WHOI-2007-04

Woods Hole Oceanographic Institution

Acoustic and Oceanographic Observations and Configuration Information for the WHOI Moorings from the SW06 Experiment

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Arthur E. Newhall, Timothy F. Duda, Keith von der Heydt, James D. Irish, John N. Kemp, Steven A. Lerner, Stephen P. Liberatore, Ying-Tsong Lin, James F. Lynch, Andrew R. Maffei, Andrey K. Morozov, Alexey Shmelev, Cynthia J. Sellers, Warren E. Witzell

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Technical Report

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Approved for Distribution:

James F. Lynch, Chair

Department of Applied Ocean Physics and Engineering

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1.0 Introduction

This document describes data, sensors, and other useful information pertaining to the moorings that were deployed from the R/V Knorr from July 24th to Aug 4th, 2006, during her first leg in support of the SW06 experiment. Most of the data mentioned here are archived at the Woods Hole Oceanographic Institution (WHOI). Relevant data from other SW06 researchers acquired in conjunction with this information, are also briefly mentioned here. To get further information on these data, the individual researcher responsible for it will have to be contacted.

1.1 The SW06 experiment

The SW06 experiment was large, multi-disciplinary, multi-institution, multi-national effort performed approximately 100 miles east of the the New Jersey coast (Figure 1.1) which lasted from mid-July to mid-September in 2006. A total of 62 acoustics and oceanographic moorings were deployed and all 62 were recovered. A few moorings had individual sensors that were missing due to fishing activity and a tropical storm which glanced by the SW06 experimental area during that time. This minor loss did not effect the overall quality, or quantity, of data which were collected at this time. The moorings were deployed in a 'T' geometry (Figure 1.2) to create an along-shelf path along the 80 meter isobath and an across-shelf path starting at 600 meters depth and going shoreward to a depth of 60 meters. A cluster of moorings was placed at the intersection of the two paths to create a dense sensor-populated area to measure 3-dimensional physical oceanography. Environment moorings were deployed along both along-shelf and across-shelf paths to measure the physical oceanography long those paths. Moorings with acoustic sources were placed at the outer ends of the 'T' to propagate various signals along these paths. Five single hydrophone receivers (SHRU) were positioned on the across shelf path and a vertical and horizontal hydrophone array (VLA/HLA) was positioned close to the intersection of the 'T' to get large antenna signal receptions from all the acoustics assets that were used during SW06.

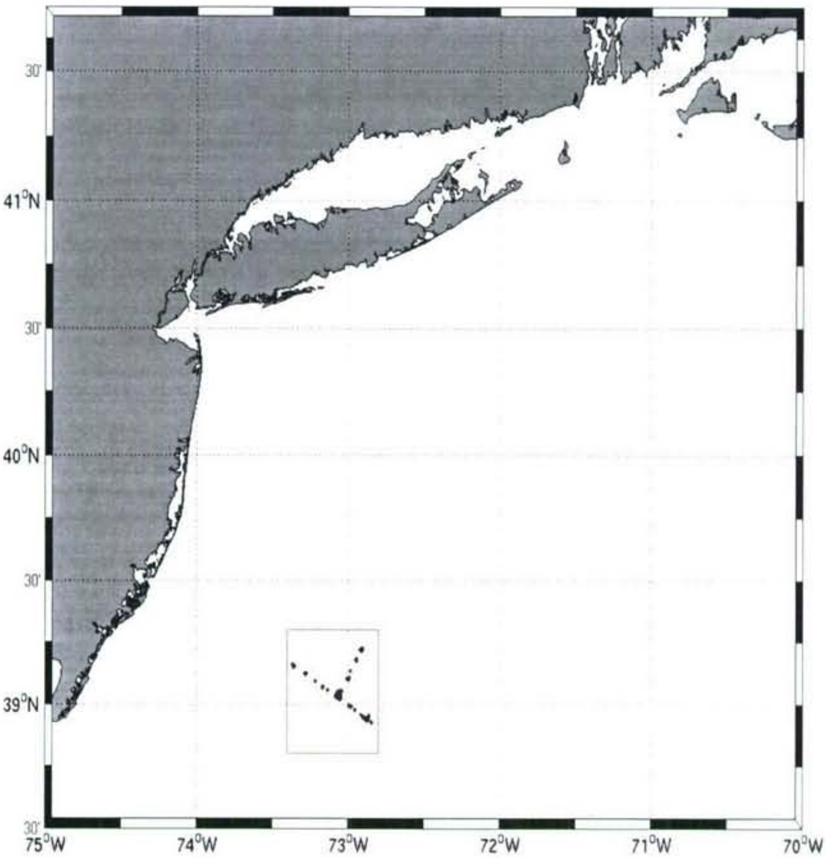

Figure 1.1 SW06 experiment area directly east of Atlantic City, NJ.

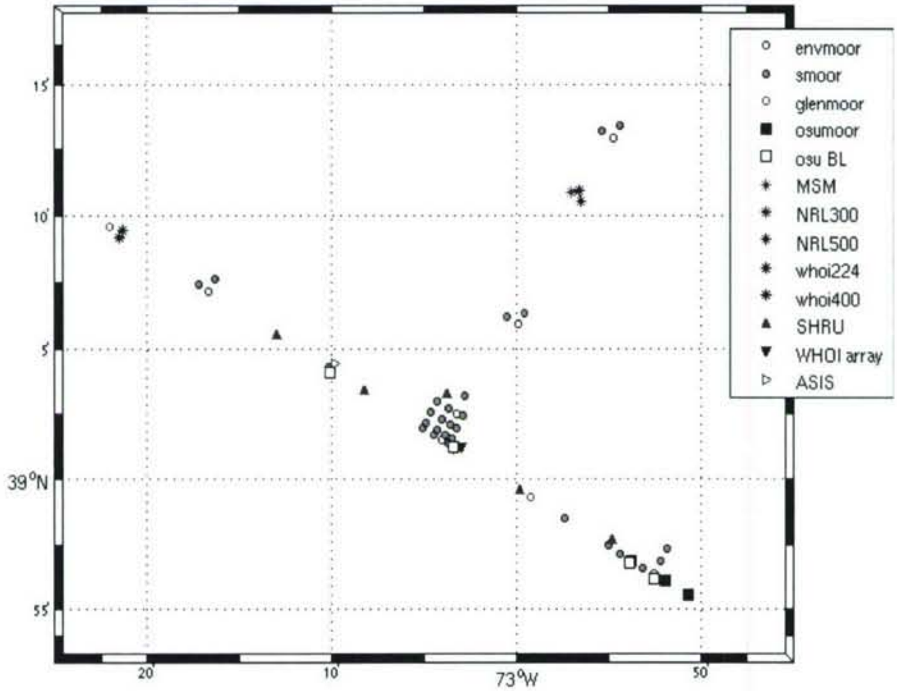

Figure 1.2: SW06 Mooring locations.

1.2 Environmental Assessment

Prior planning was key to the success of this experiment and that included having a thorough assessment of any possible marine mammal impact due to our sensors and probes. Legislative and regulatory requirements dictate that a thorough analysis of any potential impact of human-generated noise on marine mammals must be conducted prior to use of active underwater acoustic transmissions at-sea. Marine Acoustics, Inc. was chosen to study our operations, make recommendations and prepare permits. Some adjustments were made and plans were modified to insure that there would be NO impact on marine mammals from any of our sources or other instruments.

1.3 Fishing fleet contact

To notify the regional fishing fleet of our presence, we submitted a formal 'U.S Notice to Mariners' provided by the Coast Guard and also subscribed to the commercial Boatracs (tm) service. Communication is key when sharing the waters to avoid any potential problems and to protect the the fisherman's gear as well as our equipment.

'Notice to Mariners' is a service where the Coast Guard broadcasts warnings on VHF radio channel 23, which provides information critical to navigation and the safety of life at sea. This includes information and coordinates of areas that should be avoided due to oceanographic research. The Coast Guard also includes that information on their website which contains more detailed warnings to any mariner with access to a network connection. We submitted a report which was broadcast continuously throughout the duration of the SW06 experiment.

Boatracs is a commercial supplier of wireless maritime service and information. Boatracs serves over 400 commercial fleets and to our benefit serves the U.S. Northeast area. Most of the New England commercial fishing fleet is equipped with hardware to support this service. All boats equipped with their satellite terminal equipment received warnings and deployment updates for SW06. We also set up a website that was linked from the Boatracs service with complete mooring information including deployment times and locations. This information was broadcast once a day for the 2 weeks at the start of the experiment, then once a week thereafter. This service was inexpensive and well worth the cost to notify the fishing fleet of our presence and location of our sub-surface moorings where their gear could potentially become tangled or lost.

These measures were instrumental for being able to recover all 62 moorings we deployed. We found fishing gear on only 1 mooring which was located at 200 meters depth where much of the fishing was being conducted. One fisherman called our WHOI contact person to ask that we not broadcast our positions any more since he was getting updates so often. Much to his displeasure, we did not find this prudent and kept broadcasting to make sure that all fisherman knew where we were working.

1.4 Tropical storm Ernesto

The SW06 experiment was scheduled into the 2006 hurricane season. Luckily, no major hurricanes reached the SW06 site but one tropical storm, Ernesto, did manage to appear in the area and changed plans for those preparing for work at sea.

Ernesto was the first Hurricane of the 2006 Atlantic season, formed in the Caribbean on August 24th, but became a tropical storm in the evening of the August 25th. At the SW06 site, the wave and wind effects from Ernesto started at noon on September 1st and subsided at noon on September 3rd. According to the R/V Endeavor, which left the immediate area to ride out the storm in a more subdued conditions, at Ernesto's height, recorded RMS wave heights were around 6 meters (20 feet) and the sustained wind speed was approaching 40 kts (46 mph). Conditions from Ernesto can be seen in Figure 1.3.

Figure 1.3 Wave during Ernesto from the R/V Endeavor (courtesy of Andrey Scherbina).

1.5 Mooring naming designation

All moorings that were deployed were assigned a name. The name consisted of the letters 'SW' followed by a number, i.e. SW01, SW02, ... The following charts show mooring locations with their assigned mooring numbers. Figure 1.3 shows all the moorings deployed during the 1st leg of the R/V Knorr with their mooring numbers. The main chart is sub-divided into 4 sub-areas of the SW06 experiment area which are 1) along-shelf path area (Figure 1.4): those moorings that were deployed on the 80 meter isobath forming the path from the northeast tip to the intersection of the 2 main paths, 2) on-shelf area (Figure 1.6): those moorings forming the path from the northwest tip to the intersection of the 'T', 3) cluster area (Figure 1.7): those moorings that were deployed in a cluster at the intersection of the 'T', and 4) off-shelf area (Figure 1.8): those moorings that were aligned in a path going from the 'T' intersection to southeast.

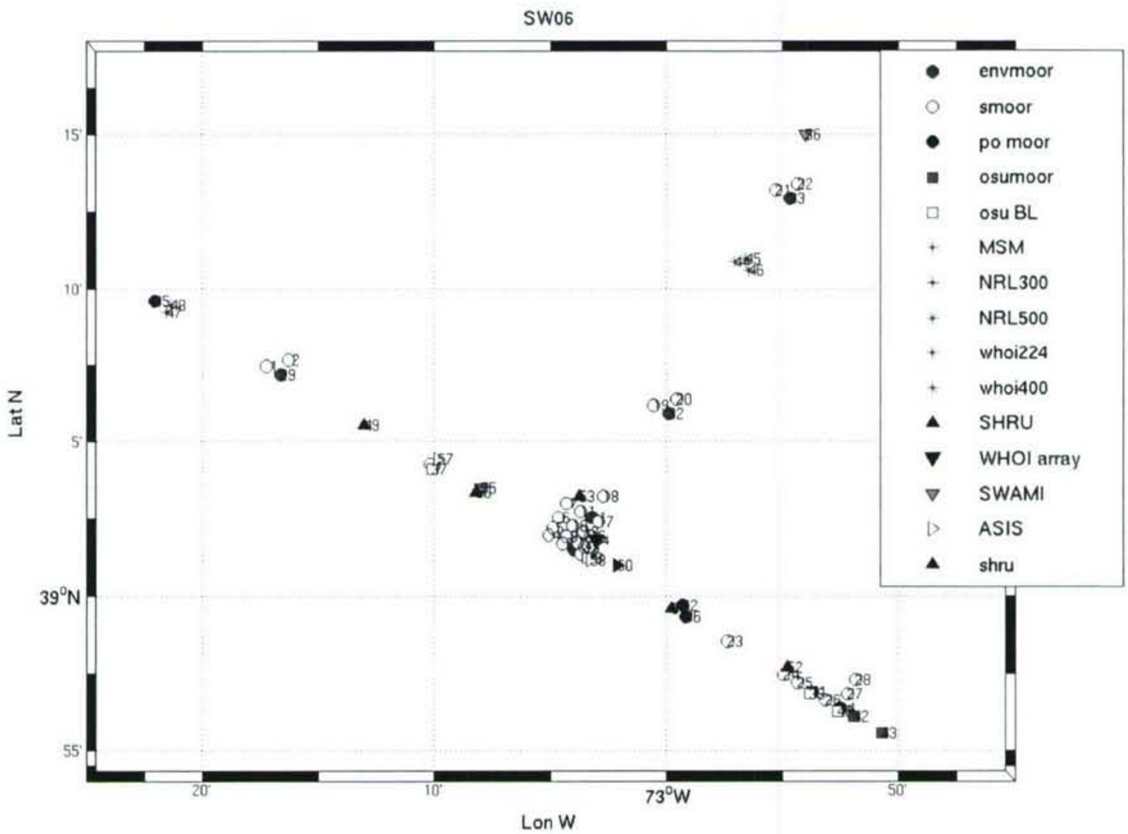

Figure 1.4 All SW06 moorings plotted with their mooring number.

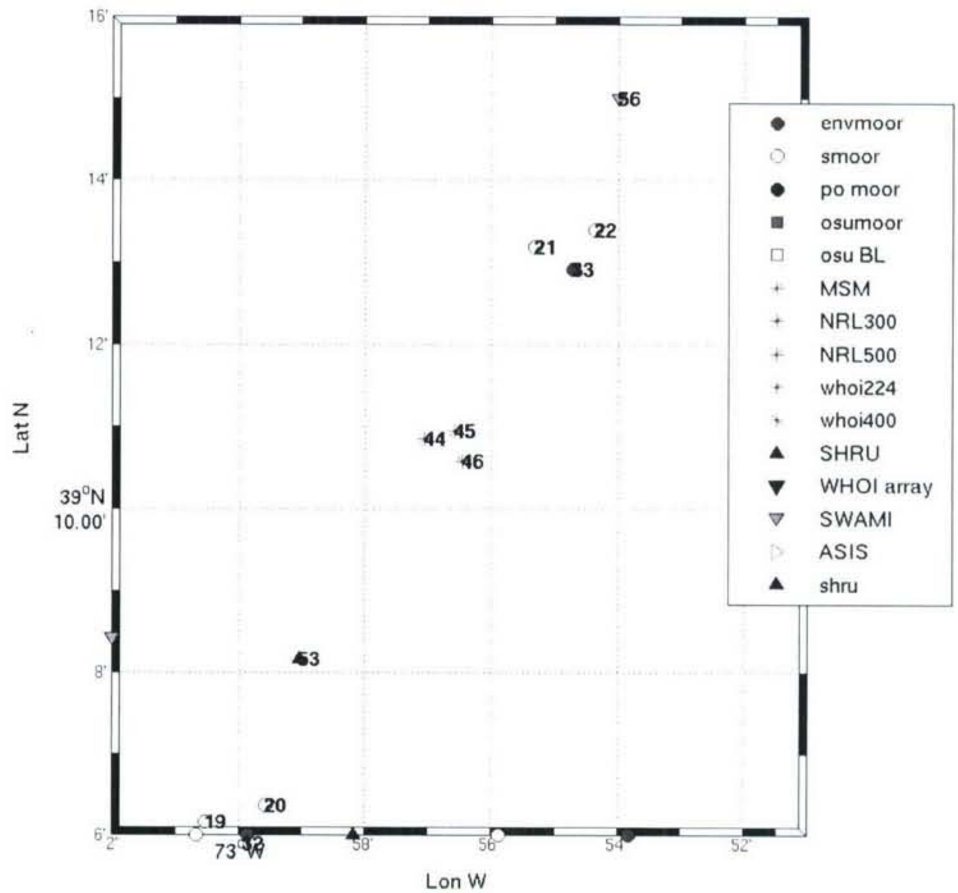

Figure 1.5 SW06 along-shelf moorings with their mooring numbers.

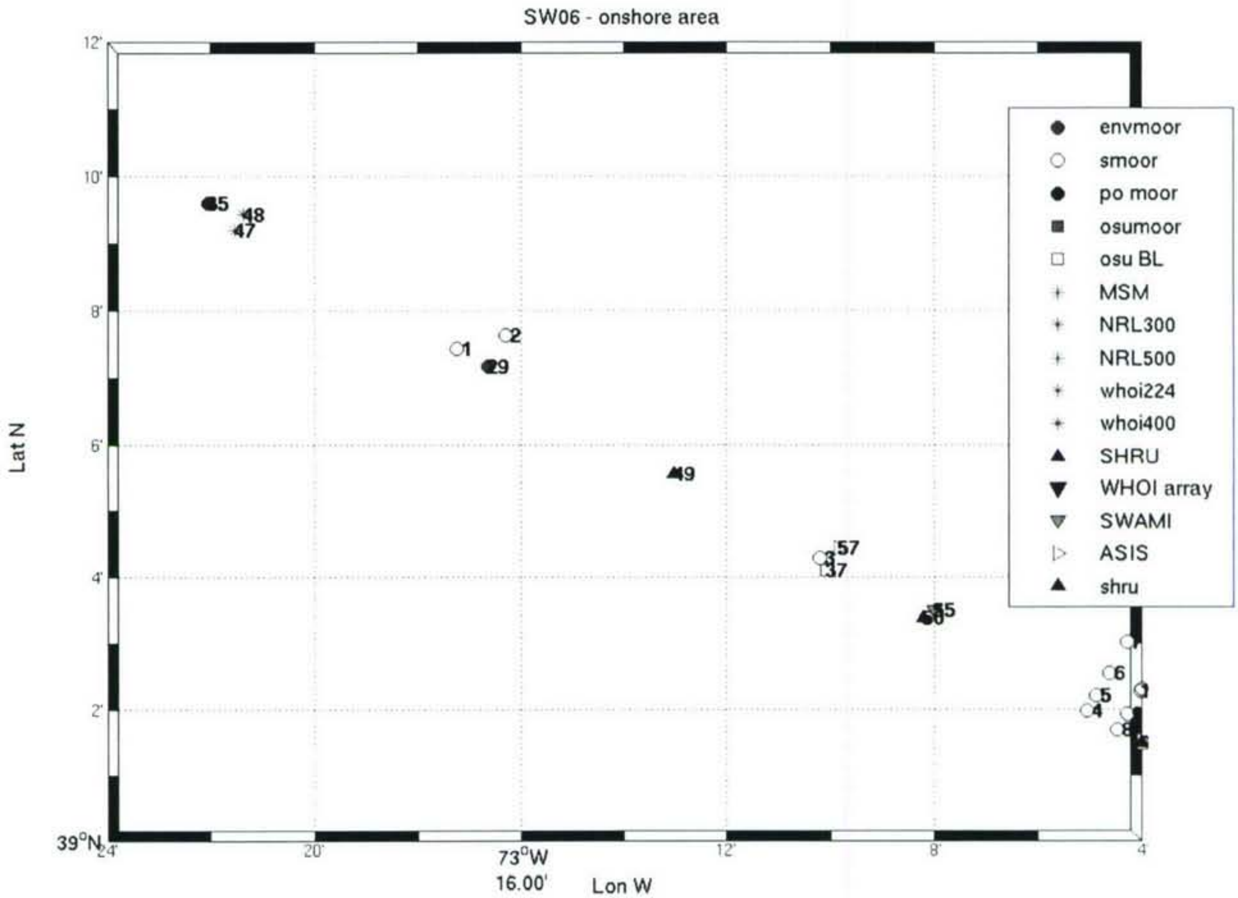

Figure 1.6 SW06 on-shore moorings with their mooring numbers.

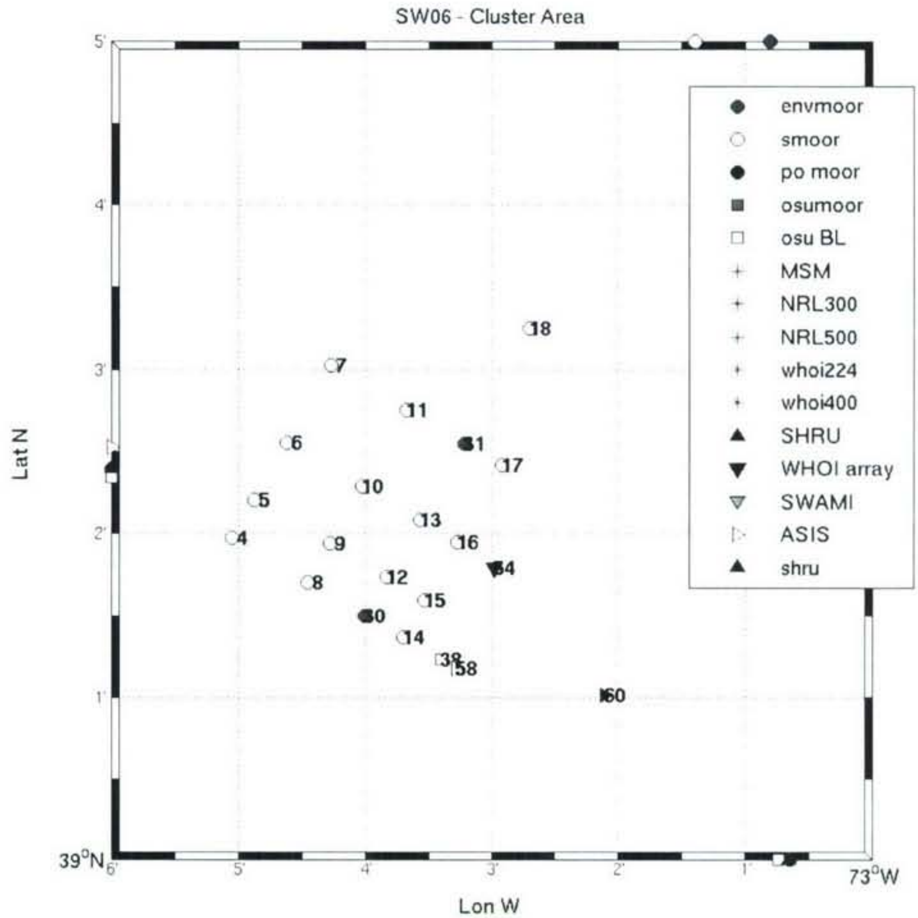

Figure 1.7 SW06 Cluster moorings with their mooring numbers.

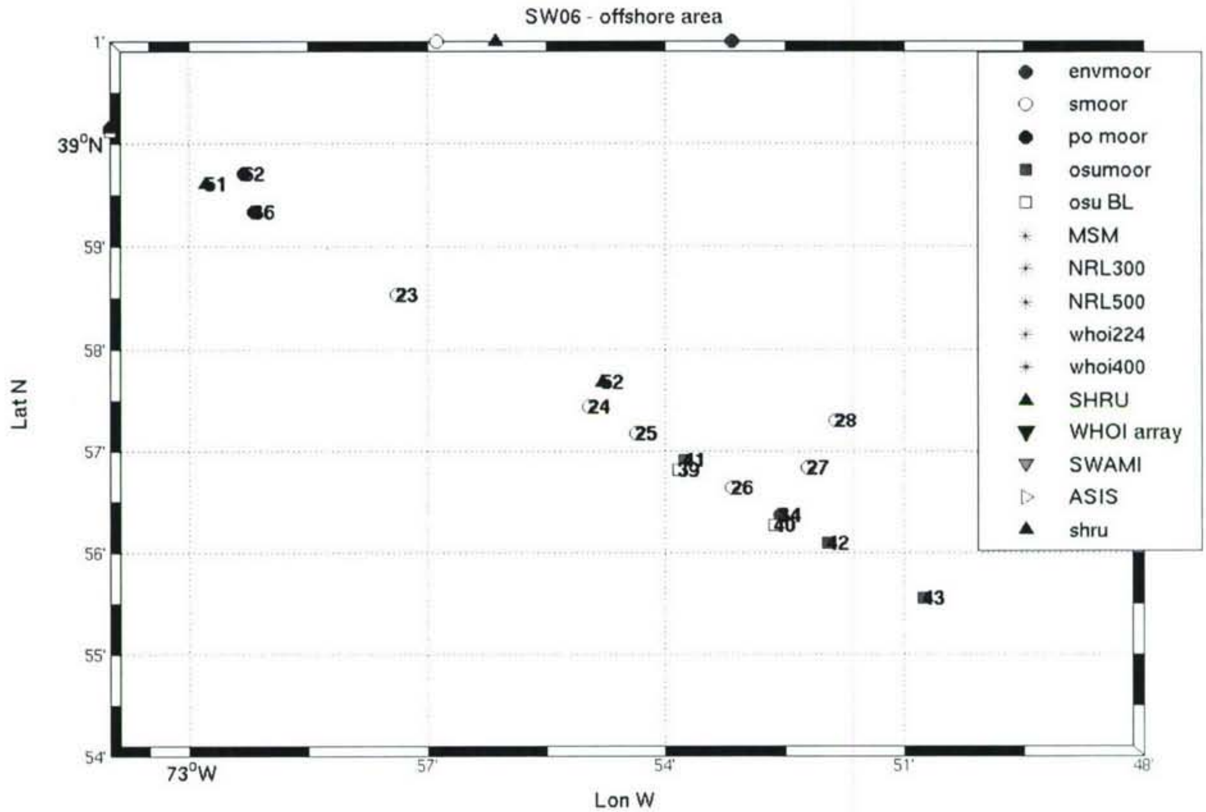

Figure 1.8 SW06 Off-shore moorings with their mooring numbers.

2.0 Personnel

2.1 SW06 Ship participation

The were 5 main vessels used in the SW06 experiment: R/V Knorr, R/V Oceanus, R/V Endeavor, R/V Sharp, and CFAV Quest. R/V Knorr, R/V Endeavor and R/V Oceanus used the Woods Hole Oceanographic Institution dock and facilities for staging and loading which sped up the process of getting each ship ready for multiple legs. The R/V Sharp used its Delaware home port for loading. The Canadian Forces Auxiliary Vessel CFAV Quest sailed out of Halifax, Nova Scotia, but made a port stop at Woods Hole mid-way through their excursion. The proposed ship schedules can be seen in Figure 2.1.

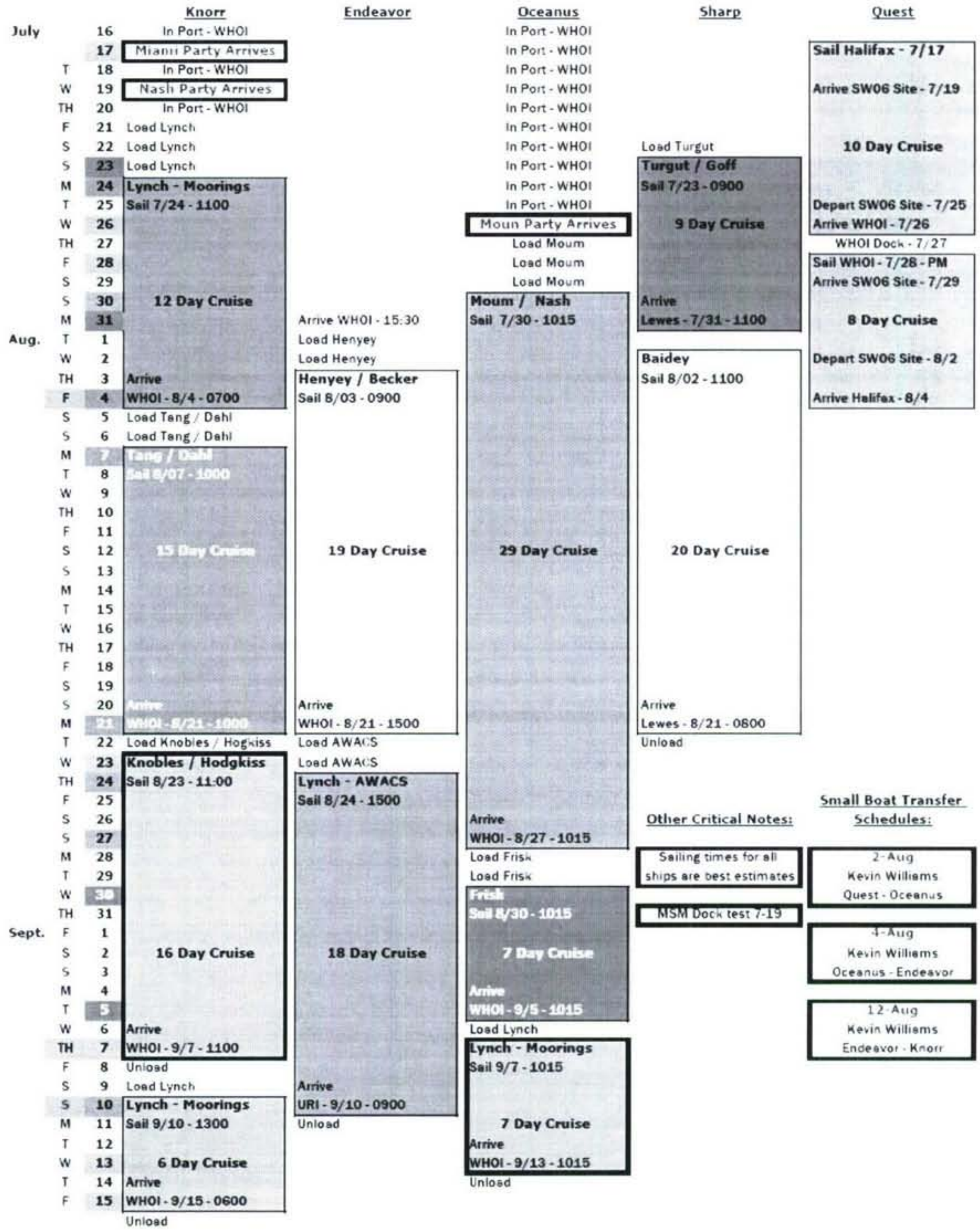

Figure2.1 SW06 Ship schedules.

2.2 R/V Knorr deployment leg participants

A large number of people participated and contributed to the success of the experiment. We are going to only list those here that were on the first leg of the R/V Knorr who were responsible for deploying all the moorings and were also responsible for most of the data presented here (Table 1). Since this was a cooperative multi-institutional effort, the investigators mentioned in this manuscript are from Woods Hole Oceanographic Institution (WHOI), University of Miami (UM), Florida Atlantic University (FAU), Oregon State University (OSU), Applied Physics Lab (APL) at University of Washington (UW), University of Texas (UT), University of Delaware (UD), and Scripps Institution of Oceanography (SIO). The principal investigators for each leg of the experiment are listed in Table 2.

Table 1: R/V Knorr deployment leg1 participants.

Name	Affiliation	Responsibilities
Jim Lynch	WHOI	SW06 Principal Investigator/Chief Scientist
Arthur Newhall	WHOI	Logistics/operations
John Kemp	WHOI	Operations coordinator
Keith von der Heydt	WHOI	Principal engineer
Nick Witzell	WHOI	Engineer
Jim Irish	WHOI	Engineer/scientist
Tim Duda	WHOI	Acoustics and physical oceanography scientist
Hans Graber	Univ. of Miami	Satellite data/scientist
Andy Maffei	WHOI	Communications
Jonathan Nash	Oregon State Univ.	OSU PO moorings/scientist
Jim Ryder	WHOI	Engineer
Neil McPhee	WHOI	Engineer
Neil Williams	Univ. of Miami	Engineer
Mike Rebozo	Univ. of Miami	Engineer
Hien Nguyen	Univ. of Miami	Engineer
Joe Gabriele	Enviro Canada	Engineer
Rafael Ramos	Univ. of Miami	Post-Doc
Alexander Lowag	Univ. of Miami	Student
Jennifer Wylie	Univ. of Miami	Student
Gina Applebee	WHOI	Student
Alexey Shmelev	WHOI	Student
Wilken-Jon von Appen	WHOI	Student
Ying-Tsong Lin	WHOI	Post-Doc
Ryan Wood	Mass Maritime Academy	Student

Table 2: Principal investigators for SW06.

SW06 Principal Investigators (PI) / Chief Scientists	
R/V Knorr	
Cruise #183 leg1	Jim Lynch (WHOI)
Cruise #184 leg2	D.J. Tang (APL/UW)
Cruise #185 leg3	David Knobles (APL/UT)
Cruise #186 leg4	Jim Lynch (WHOI)
R/V Oceanus	
Cruise #427 leg1	Jim Moum (OSU)
Cruise #428 leg2	George Frisk (FAU)
Cruise #429 leg3	John Kemp (WHOI)
R/V Endeavor	
Cruise #424 leg1	Frank Henyey (APL/UW)
Cruise #425 leg2	Jim Lynch (WHOI)
R/V Sharp	
Cruise #060622CM leg1	John Goff (UT)
Cruise #060622CM leg2	Mohsen Badiey (UDel)

3.0 WHOI Instrumentation

3.1 Introduction

To describe the temperature (sound velocity) and density structure of the slope and shelf regions of the SW06 site, and to observe the internal wave activity, an array of physical oceanographic moorings was designed and deployed. The array consisted of an across-shelf and along-shelf line of environmental moorings (Figure 1.4) which intersected in a "T". At the intersection there was a cluster of 16 moorings forming a tight 3-D array (Figure 1.7). All environmental moorings had a high-flyer marker with a temperature sensor at about 1 m depth to observe the surface temperature field.

The along-shelf moorings were placed approximately along a line at 60 degrees heading. The cross-shelf moorings were along a line at 300 degrees. The cross-shelf line direction was chosen to be a rounded number close to the direction of packets of nonlinear (solitary-type) internal waves (100-400 m wavelength, 0.7-0.8 m/s speed). These waves have been observed to propagate essentially across-shelf at a heading near 300 degrees, with some variability of direction, and with indications of curved wave fronts emanating from their region of generation. The moorings in the deepest water, at the southeast location, were placed offshore where nonlinear internal waves were expected to form by the interaction of tidal flow with the continental shelf.

To get additional physical oceanographic sensors into the array and to obtain oceanographic information at the source/receiver sites, ocean sensors were mounted on the acoustic moorings. These consisted of temperature, conductivity and pressure sensors.

In all, the SW06 program deployed:

1) 1 Sea-Bird SBE-26 SeaGauge Wave and Tide sensor
2) 12 Sea-bird SBE-37 Microcats with temperature and conductivity
3) 12 Sea-Bird SBE-37 Pumped Microcats with temperature, conductivity and pressure
4) 12 Sea-Bird SBE-37 Microcats with temperature, conductivity and pressure
5) 1 Sea-Bird SBE-16 Seacat temperature and conductivity sensor
6) 8 RD Instruments Workhorse ADCP current profilers (one with waves capability)
7) 20 Sea-Bird SBE-39 temperature sensors
8) 30 Sea-Bird SBE-39 temperature and pressure sensors
9) 120 Starmon Mini temperature sensors

This gives a total complement of 215 environmental sensors deployed in SW06 by WHOI.

For acoustic propagation studies, WHOI deployed four source moorings and six receiver moorings. The primary moored receiver site (Section 6) was situated at the along/across-shelf intersection of the principal mooring deployment lines. The 'Shark' Horizontal/Vertical Line array (HLA/VLA) consisted of 48 hydrophone channels sampling sound from 20 to 4500Hz continuously over a six week period. To study propagation directly along the across-shelf path and also to cover the area outside of the main mooring paths, five single hydrophone receivers (SHRU) (Section 5) were distributed on the across-shelf path. These receivers also sampled continuously over the 20 to 4500Hz range for six weeks. All source/receivers were outfitted with environmental sensors.

Also as part of the acoustic propagation studies, WHOI deployed four source moorings (Section 4) at the outer ends of the mooring "T" design. Two were Webb Research (WRC) linear frequency modulating (LFM) sources and two were WRC broadband sources. These transmitted frequencies from 200Hz to 550Hz and provided along and across-shelf acoustic propagation signals. All sources were kept well within EPA energy levels. (Section 1.2).

3.2 Charts

Navigation chart #12300 'Approaches to New York' (Figure 3.1) encompasses the SW06 area and shows its location relative to New York Harbor.

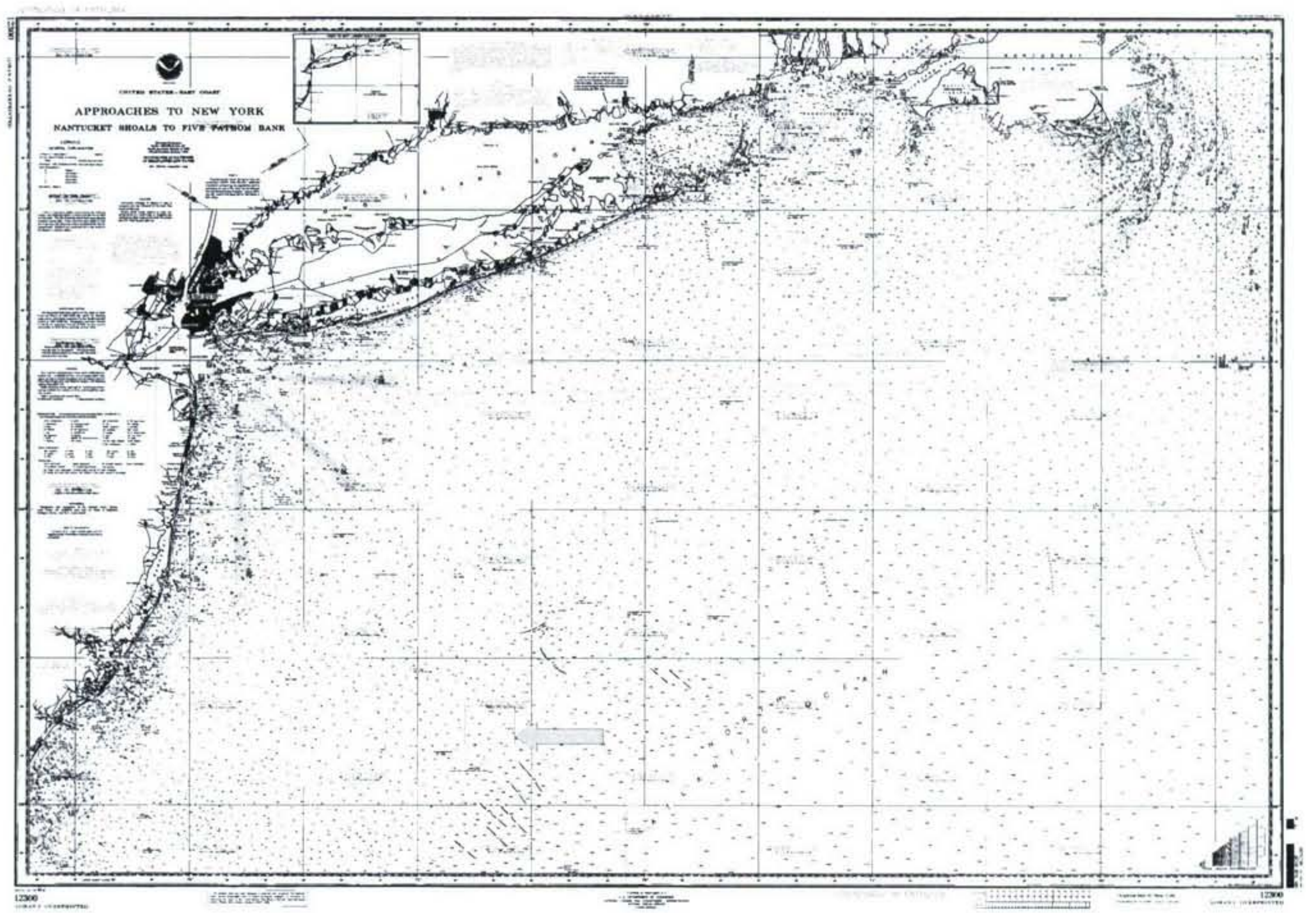

Figure 3.1 Low resolution chart #12300 'Approaches to New York'. The SW06 site is within the rectangular box indicated by the arrow.

3.4 UTC to local time conversion

All instrumentation and sensors were set to Universal Time (UTC, denoted as Z, or Zulu, in the tables). For convenience, most log book entries were time stamped to local time. To convert from UTC to local time, subtract 4 hours from UTC. Add 4 hours to local time to convert to UTC.

LocalTime = UTC - 4

4.0 WHOI moored sources

Two Webb Research Corporation (WRC) phase-encoded, single-frequency sources were deployed at the shallow end (northwest point) of the across-shelf path. These two sources were co-located to compare 224Hz and 400Hz transmissions along the same path. They were both moored low in the water column to reduce any motion caused by tides and currents and to produce optimal (low mode) acoustic propagation.

Two Navy Research Lab (NRL) sources were also deployed with WHOI support. These instruments were WRC Linear Frequency Modulating (LFM) sources transmitting at 300Hz and 500Hz and were deployed together at the outer end of the along-shelf path.

4.1 WHOI 224Hz source

Figure 4.1 WHOI 224Hz source ready for deployment from R/V Knorr.

The WHOI 224Hz source, affectionately known as 'Bertha' (Figure 4.1), is perhaps the oldest WRC source still in operational use. It was first deployed in 1981 and still works as a useful instrument. The source transmitted for 7.5 minutes every half hour starting exactly on the hour and on the half hour. There was no internal clock in the 224Hz source, but instead an accurate, temperature-stabilized oscillator. The source has to be opened to do a system time check. By the time the source was opened and the electronics removed from the pressure case after recovery, the batteries were depleted thus making an accurate time check impossible. The oscillator was synced to the SAIL clock and was 36 microsecs ahead of the time-standard GPS time clock. Signals from the end of the experiment will have to be compared with the 400Hz source to calculate any drift in the oscillator. This has not yet been done to date. The deployment position, time, and depth for the source are given in Table 3. The detailed signal characteristics for the source are described in Table 4 and the internal clock information is given in Table 5. The 224Hz source also had a number of environmental sensors attached to it which are described in Table 6.

4.1.1 SW47 – WHOI 224Hz source mooring configuration

Table 3: SW47 - WHOI 224Hz mooring specifications.

WHOI 224Hz Mooring Specifications	
Mooring Number	SW47
Deployed	Jul 30 20:56 (Z)
Recovered	Sep 12
Latitude N	39 09.2000 N
Longitude W	73 21.4911 W
Water depth (m)	58
Source depth (m, center)	49 (9 meters above bottom)
System ID	ss224

4.1.2 SW47 – WHOI 224Hz source signal information

Table 4: SW47 - WHOI 224Hz source specifications.

WHOI 224Hz Source Specifications	
Center frequency	224 Hz
Bandwidth	16 Hz
Digit length	14 cycles
Sequence length	63 digits (2^6 - 1)
Sequence time	3.9375 seconds
Transmission time	448.875 seconds (~7.5 minutes)
Sequence Law	103 (Octal)
Source level (max possible)	183 dB re 1 μPa @ 1 m
Number of sequences transmitted	114
Transmission cycle	7.5 minutes at 0, 30 minutes

Table 5: SW47 – 224Hz source internal time check.

WHOI 224Hz Oscillator	
Starting time	Day 211 Jul30 17:00 (Z)
GPS clock check	211 17:06:00
SAIL clock check	211 17:06:00.000036
Difference GPS time and start time	.000036 (36 microseconds)
Clock drift at recovery	N/A

4.1.3 SW47 – WHOI 224Hz source environmental sensors

Temperature sensors were strategically placed on the the 224Hz source mooring to record a time series of temperature changes in the water column at that location. A pressure recorder was also used to record tidal variations and get an accurate depth reading. One Seamon (tm) Tpod temperature sensor was lost due to flooding. The sensors are described in Table 6 and an image of the temperature time series is presented in Figure 4.2 .

Table 6: Sensors on SW47 - WHOI 224Hz source.

Sensor	Sensor Number	Depth (m) at deployment depth (58m)	Sampling interval (secs)	Notes
Tpod	0279	1	60	
SBE39	321	15	30	Temperature and pressure
Tpod	2086	21	30	
Tpod	0276	26	60	
Tpod	2088	31	30	
Tpod	0278	36	30	flooded
Tpod	2090	40	30	
Tpod	2037	55	30	

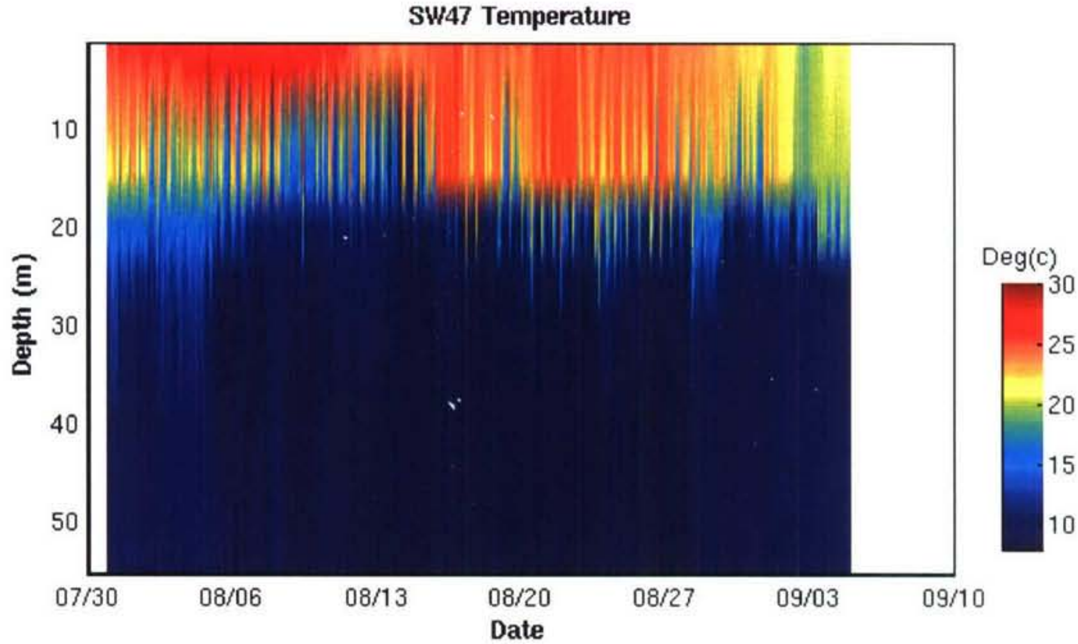

Figure 4.2 Time series of temperature at SW47 – 224Hz source mooring.

4.2 WHOI 400Hz source

The WHOI 400Hz source (figure 4.3) was also a WRC phase encoded, broadband source that was deployed in tandem with the WHOI 224Hz source at the northwest tip of the across-shelf path (see Figure 1.5). Table 7 shows the mooring specifications. Tables 8 and 9 give the signal characteristics and Table 10 shows the internal clock checks.

Figure 4.3 WHOI 400 Hz source getting ready for deployment.

4.2.1 SW48 – WHOI 400Hz source mooring configuration

Table 7: SW48 - WHOI 400Hz mooring specifications

WHOI 400Hz Mooring Specifications	
Mooring Number	SW48
Deployed	Jul 30 23:12 (Z)
Recovered	Sep 12
Latitude N	39 09.4534
Longitude W	73 21.3093
Water depth (m)	58
Source depth (m, center)	49 (9 meters above bottom)
Tpod #0271	50 m

4.2.2 SW48 – WHOI 400Hz source signal information

Table 8: SW48 - WHOI 400Hz source specifications.

WHOI 400Hz Source Specifications	
Center frequency	400 Hz
Bandwidth	100 Hz
Digit length	4 cycles
Sequence length	511 digits
Sequence time	5.11 seconds
Transmission time	449.68 seconds (~7.5 minutes)
Sequence Law	1021 (Octal)
Number of sequences transmitted	88
System ID	sys09

4.2.3 SW48 – WHOI 400 Hz source environment sensors

Table 9: Sensors on SW48 - WHOI 400Hz source.

Sensor	Sensor Number	Depth (m) at deployment depth (58m)	Sampling interval (secs)	Notes
Tpod	0271	1	30	On hi-flyer

Table 10: SW48 – 400Hz source time checks.

WHOI 400Hz Source Clock	
Starting time	Day 211 jul30 19:00 (Z)
Deploy GPS clock check	211 19:39:26
Deploy SAIL clock check	211 19:39:26.000036
Deploy Internal clock	211 19.39:26.024980
Difference GPS time and start time	.024980 secs
Recovery Internal clock	255 20:42:07
Recovery Sail clock	255 20:42:07.112560
Difference at recovery	.087396 secs (slower)
Recovery GPS sync check	255 20:02:00
Recovery SAIL sync check	255 20:01:59.999998

4.3 WHOI 224Hz and 400Hz source timekeeping

The master clock used in SW06 to sync all the sources was a GPS receiver with a one pulse per minute output. All times are referenced to the GPS master clock. The SAIL clock is a device that latches time from an input pulse. It uses an external 1MHz reference frequency from an EFRATOM Rubidium Standard. The SAIL clock drifted about 4 microseconds per day and was zeroed at the start of the recovery cruise.

The 400Hz system clock was queried via a SAIL connection through the end cap. The system responds with a time and a generated pulse at what the system thinks is the time at that moment. The pulse latches with the SAIL clock and the difference is checked to the GPS master clock to get the actual, accurate time. Assuming the system clock slows linearly, the differences between start and end times can be used to compensate for system clock drift.

These time checks and syncs can be seen in Table 5 for the 224Hz source and Table 10 for the 400Hz source.

4.4 NRL 300Hz and 500Hz LFM sweep sources

Two Navy Research Lab (NRL) WRC Linear Frequency Modulating (LFM) sources were deployed together at the outer end of the along-shelf path. They both were on the same schedule as the WHOI 224Hz and 400Hz sources, transmitting for 7.5 minutes every 30 minutes starting on the hour. The 300Hz source linearly swept over 270-330 Hz and the 500Hz source (Figure 4.4) linearly swept 470-530 Hz in 2.048seconds every 4 seconds during their scheduled transmission cycle. Each also had a .2048 seconds (10% of transmission) amplitude taper (between 0 and 100% power) at the beginning and end of each transmission to allow for graceful ramping on and off. Tables 11 and 12 show the source mooring configuration and Tables 13 and 14 describe the source specifications. The 300Hz source was also instrumented with temperature sensors as seen in Table 15. An image of the temperature time series is shown in Figure 4.5.

Figure 4.4. NRL 500Hz source on deck.

4.3.1 NRL source electronics modification and issues

Both the 300Hz and 500Hz LFM sources were originally designed to transmit continually as soon as they were started. However, we wanted them to follow the same sampling scheme as the other moored sources (transmit every ½ hour), so some modification was necessary. In doing this, a timing problem became apparent after several days of testing as the transmission start time was being skewed by approximately one second per day. We determined that this was occurring because, during the 22.5 minutes of off time, the rubidium (Rb) frequency standard was being disabled to save power and the system allowed the a Dallas real time clock (RTC) to take over. The Dallas clock contained an oscillator running at 32,768 Hz, and was not very precise. Of course, the simplest fix would have been to rewrite the operating code such that the Rb standard would remain powered during the off time. This, however, proved to be impossible.

We elected to modify the electronics such that the Rb standard would remain powered. Our intent was to implement these modifications such that the sources could easily be returned to their original configuration. This necessitated the design of two printed circuit cards, one to adapt the systems to operate using a Dallas RTC configured to operate with an external reference of 32,768 Hz and one to synthesize 32,768 Hz from the 10 MHz supplied by the Rb oscillator. A hand wired card was also required to insure that the 32,768 Hz signal would be uninterruptable during the short transition between deck mode and deploy mode, during which time power is removed from the system.

Once implemented, the above mentioned modifications affected the sources in three ways:

1) The interval between "on" times becomes very precise and is as stable as the rubidium frequency standard.
2) We were able to control the transmission schedule as planned.
3) The stand-by power is increased from .5 Watts to approximately 13 Watts.

The increased standby power requires that the system's endurance be recalculated. With a total of 1,800 "D" cells in each source, the system endurance was about 33 days.

The clocks had to be set by hand prior to deployment. No accurate external clock could be used to sync up the source's internal clocks. The time had to be set by hitting a <return> when the current time was being set. This meant that the clocks were only good to +- 1 second accuracy or as good as the reflexes of the person setting the time.

Another very odd problem, which we still don't understand, showed up after reviewing the data that was received. Every day at 0500 hrs (UTC) the 300Hz source would miss a cycle. All other transmissions were fine.

4.3.2 Mooring configuration

Table 11: SW45 - NRL 300Hz source mooring configuration.

NRL 300Hz Source Mooring Configuration	
Mooring Number	SW45
Deployed	Jul 28 15:26 (Z)
Recovered	Sep 13
Latitude N	39 10.9574
Longitude W	72 56.575
Water depth (m)	82.5
Source depth (m, center)	72

Table 12: SW46 - NRL 500Hz source mooring configuration.

NRL 500Hz Source Mooring Configuration	
Mooring Number	SW46
Deployed	Jul 28 17:24 (Z)
Recovered	Sep 13
Latitude N	39 10.587
Longitude W	72 56.458
Water depth (m)	84
Source depth (m, center)	74.5
Tpod #0274	74 m (on source)

4.3.3 Signal information

Table 13: SW45 - NRL 300Hz LFM source specifications.

NRL 300Hz LFM Source Specifications	
Center frequency	300 Hz
Bandwidth	60 Hz
Signal type	Increasing LFM
Signal sample frequency (Hz)	5000
Transmission duration (secs)	2.048
Transmission taper duration (secs)	.2048 (10%)
Transmission period (secs)	4
Transmission schedule	7.5 minutes @ 0,30 minutes
Source level (maximum possible)	183 dB re 1μPa @ 1 m

Table 14: SW46 - NRL 500Hz LFM source specifications.

NRL 500Hz LFM Source Specifications	
Center frequency	500 Hz
Bandwidth	60 Hz
Signal type	Increasing LFM
Signal sample frequency (Hz)	5000
Transmission duration (secs)	2.048
Transmission taper duration (secs)	.2048 (10%)
Transmission period (secs)	4
Transmission schedule	7.5 minutes @ 0,30 minutes
Source level (maximum possible)0	183 dB re 1μPa @ 1 m

4.3.4 Environmental sensors on SW45 – 300Hz Source

Table 15: SW45 - 300Hz source mooring specifications.

Sensor	Sensor Number	Depth (m) at deployment depth (82.5m)	Sampling interval (secs)	Notes
Tpod	2078	1	30	lost
SBE39	3130	15	30	T/P
Tpod	2079	20	30	
Tpod	2080	25	30	
Tpod	2081	30	30	
Tpod	2083	35	30	
Tpod	2084	40	30	
Tpod	2085	45	30	
Tpod	2091	50	30	
Tpod	2092	60	30	
Tpod	2093	68	30	
Tpod	2100	72	30	

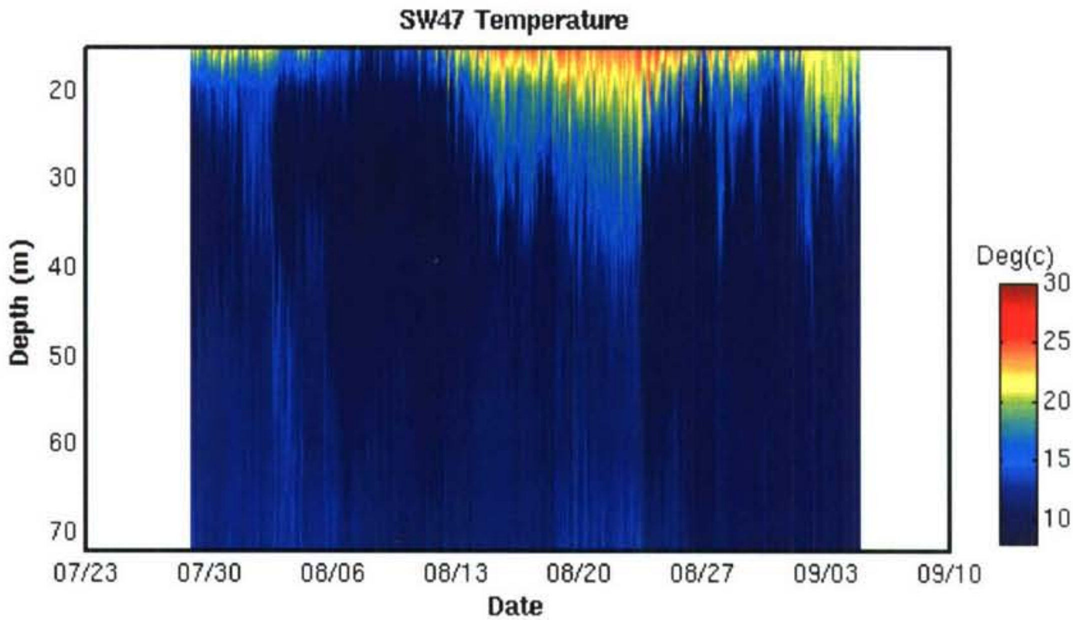

Figure 4.5 SW45 mooring temperature record.

5.0 SHRU (Single Hydrophone Receiving Unit)

Five low cost, fast sampling, Single Hydrophone Receiving Units (SHRU) were constructed at WHOI to expand the coverage of acoustic sampling. An image of the SHRU just before deployment can be seen in Figure 5.1. Four were placed about 4 km apart along the across-shelf path, and one was initially going to be placed on the along shelf path but was repositioned to the cluster area. The repositioning was due in part as a backup to the Shark HLA/VLA system and to also complete a nicely spaced receiver array along the across-shelf path. Sampling specifications are provided in Table 16. Mooring information for all five are presented in Tables 17-21.

5.1 SHRU mooring configuration

Figure 5.1 SHRU just before deployment.

Table 16: SHRU sampling specifications.

Sampling rate (Hz)	9765.625 (2.5e6/256)
Number of channels	1
Data record length (bytes per record)	1250000 bytes
Header record length (bytes per record)	1024 bytes
Total record length	1251024 bytes
Number of data samples per record (2 bytes each)	625000
Record length	64 sec
Number of records per file	128 (~136.5 min)
Disk storage	60 GB
Mission (battery life and data storage)	~35.5 days
Data file size	160,131,072 bytes
Data storage size per day	~1.6 GB /day

Table 17: SW51 - SHRU 1

SHRU #1 Mooring SW51	
Deployment location	38 59.5965 N 72 59.8082 W
Date deployed	Jul 26 16:44 (Z)
Date recovered	Sep 13 16:20 (Z)
Recording started	Jul 26 11:07 (Z)
Recording stopped	Aug 31 05:22 (Z)
Water depth	85m
Hydrophone depth	78m (7m above bottom)
Time rel to GPS @ deployment	shru lags by 2867 microsecs
Time rel to GPS @ recovery	shru lags by 71600 microsecs
Net drift	74467 microsecs
Hydrophone number	208181
Number of restarts (from log file)	19

Table 18: SW52 - SHRU 2

SHRU #2 Mooring SW52	
Deployment location	38 57.6715 N 72 54.8139 W
Date deployed	Jul 26 15:06 (Z)
Date recovered	Sep 13 17:30 (Z)
Recording started	Jul 26 14:18 (Z)
Recording stopped	Aug 31 08:25 (Z)
Water Depth	107m
Hydrophone depth	100m (7m above bottom)
Time rel to GPS @ deployment	shru lags by 2884 microsecs
Time rel to GPS @ recovery	shru lags by 1537 microsecs
Net drift	12486 microsecs
Hydrophone number	208176
Number of restarts (from log file)	19

Table 19: SW53 - SHRU 3

SHRU #3	Mooring SW53
Deployment location	39 03.252 N 73 03.738 W (planned location changed)
Date deployed	Jul 28, 22:55 (Z)
Date recovered	Sep 12 23:00 (Z)
Recording started	Jul 28 20:41(Z)
Recording stopped	Sep 02 14:32 (Z)
Water Depth	82m
Hydrophone depth	75m (7m above bottom)
Time rel to GPS @ deployment	shru lags by 2871 microsecs
Time rel to GPS @ recovery	shru lags by 12260 microsecs
Net drift	15131 microsecs
Hydrophone number	208177
Number of restarts (from log file)	17

Table 20: SW50 - SHRU 4.

SHRU #4 Mooring SW50	
Deployment location	39 03.391 N 73 08.214 W
Date deployed	Jul 29 17:28 (Z)
Date recovered	Sep 12 22:05 (Z)
Recording started	Jul 29 14:42 (Z)
Recording stopped	Sep 03 09:14 (Z)
Water Depth	67m
Hydrophone depth	60m (7m above bottom)
Time rel to GPS @ deployment	shru lags by 2886 microsecs
Time rel to GPS @ recovery	shru lags by 11500 microsecs
Net drift	8614 microsecs
Hydrophone number	208187
Number of restarts (from log file)	19
Mini-tpod T0266 depth	Above hydrophone

Table 21: SW49 - SHRU 5

SHRU #5 Mooring SW49	
Deployment location	39 05.548 N 73 13.022 W
Date deployed	Jul 29, 19:50 (Z)
Date recovered	Oct 4 (see tale below, sec 5.1.1)
Recording started	Jul 29 19:04 (Z)
Recording stopped	Sep 04 13:25 (Z)
Water Depth	65m
Hydrophone depth	58m (7m above bottom)
Time rel to GPS @ deployment	shru lags by 2853 microsecs
Time rel to GPS @ recovery	N/A
Net drift	N/A
Hydrophone number	208190
Number of restarts (from log file)	N/A

5.1.1 Missing SHRU tale

The only WHOI mooring that was not retrieved during the recovery legs in mid-September was the Single Hydrophone Receiving Unit (SHRU) at mooring SW49. It was missing and so was left behind. We could live with only losing one mooring.

But on October 3, WHOI got a call from Virginia Beach fishing boat captain Mark Hodges. He had found the SHRU and it was intact! A week later we picked up the SHRU in VA and happily gave Mark our appreciation.

The SHRU was full of data! It still had the external temperature sensor on it which showed it had lasted on site until Tropical Storm Ernesto. The acoustic release was flooded, corroded and had pieces missing. It was speculated the the release flooded early and, due to corrosion and stress from the tropical storm, let go.

5.2 SHRU data acquisition and data format

Data from all the 5 independently deployed single channel systems is in a nearly identical format to the Shark HLA/VLA data that will be discussed in Chapter 6. The sample rate and encoding of the 24 bit data are identical, however, the SHRU data records have a 1024 byte header instead of a trailer as in Shark data. The header structure for the SHRU's is the same; however, there is no long baseline (LBL) data and the size of records and files is different. A SHRU record is 64 seconds of data at the same 9765.625 sample rate There are 625,000 samples in a record for a total of 1,251,024 bytes. A file consists of 128 records and is therefore 160,131,072 bytes. The flat passband is .453 times the sample rate (4424 Hz) and the -3dB point is .49 times the sample rate.

The passband ripple is .005 dB and the group delay is a constant 39 sample periods. The SHRU hydrophones were attached to the mooring cable and away from the electronics package 7.06m above the bottom.

SHRU data was acquired using a Persistor, model CF2 which employs a Motorola 32 bit processor and therefore, stores data big endian, i.e. the higher order byte of a 2-byte sample value occurs first in ascending memory space. Another difference in the SHRU data set to that of the Shark VLA/HLA is that the fixed gain is 26 dB (or a fixed gain of 20 in linear scale). Therefore when normalizing SHRU data to volts at the sensor output, a fixed gain of 20 should be used.

If the data was recorded from one day to the next past midnight, the day did not not get incremented until the next new file was created. The day rollover increment will have to be incorporated into the software that reads the DRH. This has not been done to date.

The 1024 byte structure below is written as a Data Record Header (DRH) by the SHRU.

```
struct data_rec_h                                       // 1024 bytes total          (DRH bytes)
{
        unsigned char      rhkey[4];                    // header key, "DATA"    (0-3)
        unsigned int       date[2];                     // date[0]=year, date[1]=Year-day#    (4-7)
        unsigned int       time[2];                     // time[0] = (hours*60 + minutes)      (8-11)
                                                        // time[1] = (seconds*1000 + milliseconds)
        unsigned int       microsec;                    // microseconds, (12-13)
        unsigned int       rec;                         // this record #       (14-15)

        int                ch;                          // # channels    <1>    (16-17)
        char               unused1[2];                  // (18-19)
        long               npts;                        // # sample periods per record, 625,000 for SHRU  (20-23)
        float              rhfs;                        // sample rate in Hz <9765.625> ,  19531.25 B/s      (24-27)
        long               rectime;                     // record time in microsec <64,000,000>      (28-31)
                                                        // 128 recs* 1,251,024 B/rec  = 160,131,072 bytes per file
        char               rhlat[16];                   // long, ascii DDD MM SS.T N or S,  for SW06 N/A   (32-47)
        char               rhlng[16];                   // long, ascii DDD MM SS.T E or W,  for SW06 N/A   (48-63)

        unsigned long      nav120[7][4];                // for Shark LBL nav, 112 bytes    (64-175)  N/A for SHRU
        unsigned long      nav115[7][4];                // for Shark LBL nav, 112 bytes    (176-287) N/A for SHRU
        unsigned long      nav110[7][4];                // for Shark LBL nav, 112 bytes,   (288-399)  N/A for SHRU

        char               POS[128];                    // MOMAX4 POS string for lat/long   N/A for SHRU   (400-527)
        char               unused2[208];                //  (528-735)

        int                nav_day;                     // date/time of this LBL suite    (736-737)  N/A for SHRU
        int                nav_hour;                    //  (738-739)
        int                nav_min;                     //  (740-741)
        int                nav_sec;                     //  (742-743)
        int                lblnav_flag;                 //  (744-745)
        char               unused3[2];                  //  (746-747)
        long               record_length;               // record length in bytes; 1,251,024    (748-751)

        int                acq_day;                     // (752-753)   N/A for SHRU
        int                acq_hour;                    //  (754-755)              "
        int                acq_min;                     //  (756-757)              "
        int                acq_sec;                     //  (758-759)              "
        int                acq_recnum                   // (760-761)               "
        int                ADC_tagbyte                  // (762-763)               "
        int                glitch_code;                 // (764-765)               "
        int                boot_flag                    // (766-767)               "

        char               internal_temp[16];           //  temp for MOMAX & SHRU   (768-783)
        char               bat_voltage[16];             //  Vmain for MOMAX & SHRU   (784-799)
        char               bat_current[16];             //  (800-815)
        char               status[16];                  //  (816-831)
        char               proj[16];                    // project name, <SW06 >  (832-847)
        char               aexp[16];                    //     (848-863)
        char               vla[16];                     // <PHONE SENS  -170>    (864-879)
        char               hla[16];                     // < -170 >       (880-895)
        char               fname[32];                   // ascii file name    (896-927)
```

```
        char        record[16];        // ascii representation of rec #, REC ####  (926-943)
        char        adate[16];         // ascii representation of date, mo/da/yr  (944-959)
        char        atime[16];         // ascii rep of rec time, hr:mn:ss.mmmmmmm  (960-975)

        long        file_length;       // 128 record file len, SHRU, 160,131,072 bytes  (976-979)
        long        total_records      // total # records to date  (980-983)
        char        unused4[2];        //  (984-985)
        int         adc_mode;          // 0 =fixed point, 1 = 24 bit, <2 = pfp>  (986-987)
        int         adc_clk_code;      // ADC clock timebase divider, SHRU=1  (988-989)
        char        unused5[2];        //  (990-991)

        long        timebase;          // 5 MHz  Austron  (992-995)
        char        unused6[12];       //  (996-1007)

        char        unused7[12];       //  (1008-1019)
        char        rhkeyl[4];         // end of rec header key "ADAT"  (1020-1023)
};
```

The "C" coded method of normalizing the stored 16 bit integer SHRU data to a value of volts from the hydrophone is:

```
exp =  val[i] & 0x0003
gain = 10^(26/20) * 2^(exp*3)
voltage (at hydrophone output) = (((val[i] >> 2) / 8192) * 2.5v) / gain
```

A method used when data are brought into Matlab (tm) for processing is to read the data as 16 bit shorts. Data will become doubles in Matlab. SHRU data are stored big endian so Matlab has to be instructed to read it accordingly. The gain normalizing algorithm shown below accommodates the SHRU ADC fixed gain of 26 dB.

```
data=data/4;
mantissa=floor(data);
gain=4*(data-mantissa);
gain=(2*(ones(1,BLKSIZE))).^(3*gain);
voltage=(2.5)*((data)./gain)/8192/20;
```

Peak to peak voltage at the output of a phone is 1Vpp. (Vpp = -9 dBv). Since the SHRU hydrophone sensitivity is 170 dB re 1 μPa per 1 volt, to convert the data time series, after normalizing as described above, from volts to microPascals (μPa) is:

$$\mu\text{Pa} = \text{voltage} * 10^{(170/20)}$$

Standard processing procedures can be performed in either microPascals or volts. The conversion of dB levels from volts to microPascals is:

$$\text{dB re } 1\ \mu\text{Pa} = \text{dB re } 1 \text{ volt} + 170$$

Data were stored as unsigned short int (2 bytes), with the upper byte occurring first followed by the lower byte. The bits are high true, i.e. an active bit is a "one" or high logic level. The 16 bit sample consists of a 14 bit, 2's complement mantissa (M12 is msb), in the low part of the word with the 2 gain bits in the lower part, (G1 is msb). The sign bit is in the 15th bit position. Bits 0 through 7 are the low byte and bits 8 through 15 are the high byte of the stored sample.

```
Bit 15   14   13   12   11   10   09   08   07   06   05   04   03   02   01   00
    SN  M12  M11  M10  M09  M08  M07  M06  M05  M04  M03  M02  M01  M00  G1   G0
   {+/-}{          13 BIT MANTISSA                                     }{'GAIN'}
```

The 4 gain bit combinations indicate the number of 3 bit right shifts that must be applied to the mantissa to recreate the 24 bit ADC word.

00 -> no right shift of 14 bit mantissa required
01 -> mantissa must be right shifted 3 bits
10 -> mantissa must be right shifted 6 bits
11 -> mantissa must be right shifted 9 bits

Recreated 24 bit ADC word; bit 23 is the sign bit, 2nd row bits are from the stored 16 bit word, unused bits (--) assume sign bit value

GAIN bits = 00 (largest values)
23 22 21 20 19 18 17 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01 00
15 14 13 12 11 10 09 08 07 06 05 04 03 02 -- -- -- -- -- -- -- -- -- --

GAIN bits = 01
23 22 21 20 19 18 17 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01 00
15 -- -- -- 14 13 12 11 10 09 08 07 06 05 04 03 02 -- -- -- -- -- -- --

GAIN bits = 10
23 22 21 20 19 18 17 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01 00
15 -- -- -- -- -- -- 14 13 12 11 10 09 08 07 06 05 04 03 02 -- -- -- --

GAIN bits = 11 (smallest values)
23 22 21 20 19 18 17 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01 00
15 -- -- -- -- -- -- -- -- -- 14 13 12 11 10 09 08 07 06 05 04 03 02 --

5.3 SHRU acoustic data and data filename convention

A sample spectrogram of the SHRU acoustics data is shown in Figure 5.2. The signal to noise was excellent for all five SHRUs. This spectrogram shows 8 different signals: 224Hz from 'Bertha', NRL 300Hz LFM, WHOI 400Hz, NRL 500Hz

LFM, 800Hz and 1600Hz from the Miami Sound Machine, and 1200Hz and 3500Hz chirp signals generated by the CFAV Quest. Besides our own signals, we have recorded signals of thunder, numerous ships passing by, dolphin clicks, and some unexpected, and unexplained, signals.

All SHRU data files are named using the date and time from the first record in the file. The filename convention is

MMDDhhmm.dat

where MM is the month, DD is the day, hh is the hour, and mm is the minute of the first record in that file. All data between records are seemless without any time delay.

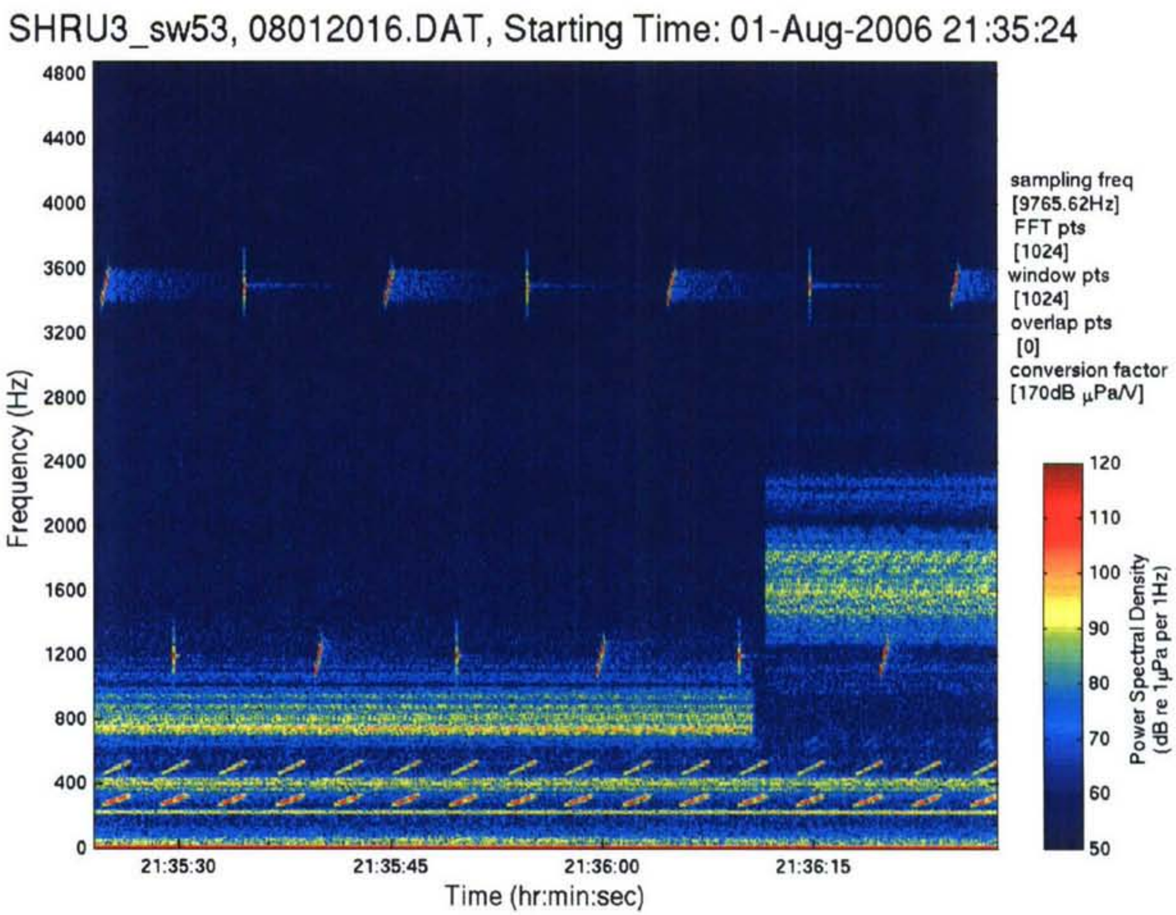

Figure 5.2 SHRU #3 (near the cluster) spectrogram showing 8 different signals.

5.4 ShruView application

The amount of data and information collected in SW06 presents a challenge of how to display and access that data. The ShruView application is a web-based, beta software application designed to address that problem. The ShruView displays multiple data sets synchronized by time every 10 minutes for viewing, network download, and analysis of data related to a specific SHRU receiver. Data sets and information provided by the application include a spectrogram of the acoustics signal at a given time, an audio version of the same signal seen on the spectrogram, the water column temperature profile from a site nearby, a clickable display time and temperature image, a chart of the SW06 site with ship positions and mooring locations at that time, and other useful information. This tool is designed to quantify the integrity of the data, to compare multiple, concurrent data sets, and to help to choose portions of the data which contain characteristics desirable for further analysis. The main display can be viewed in Figure 5.3.

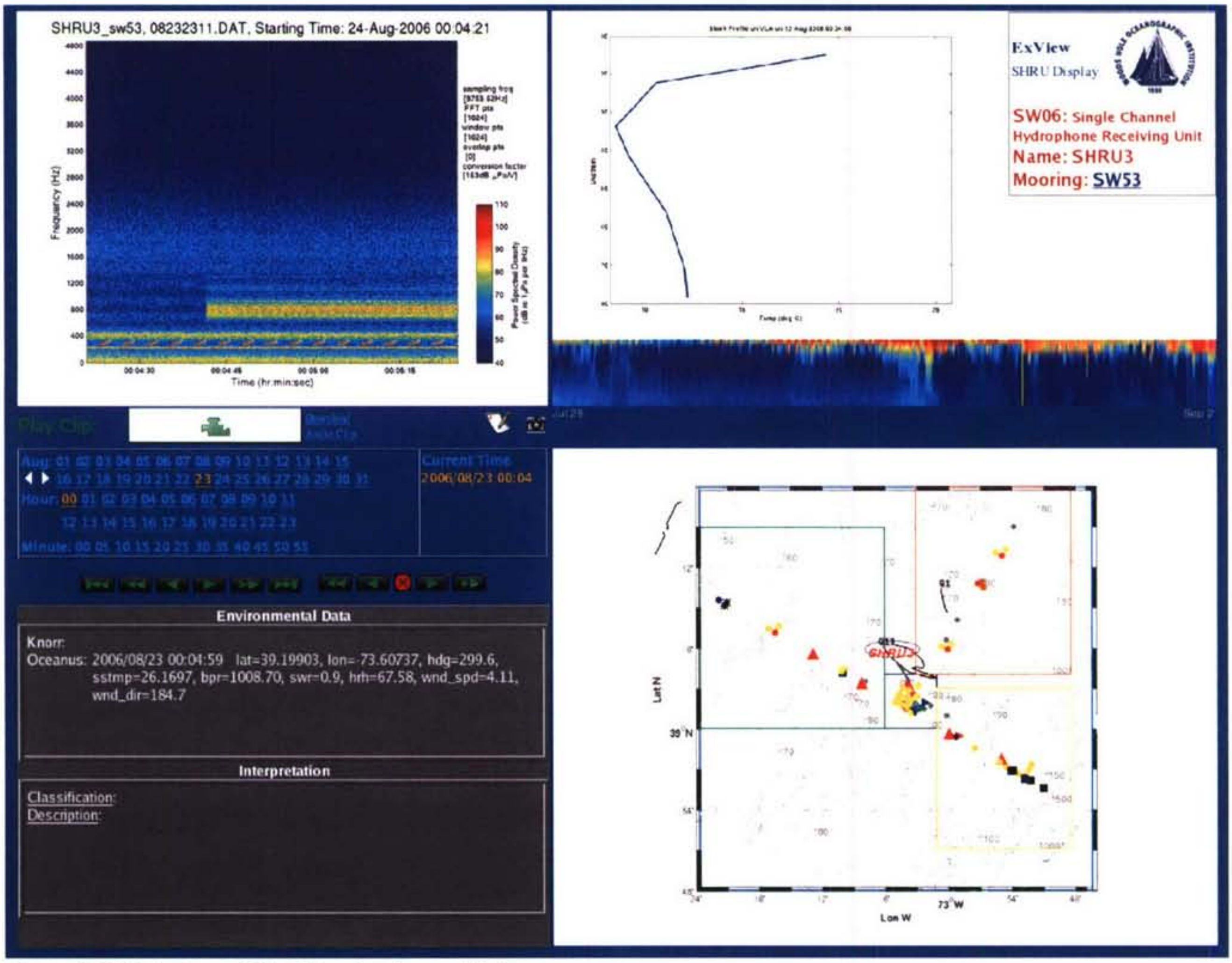

Figure 5.3 Main view of ShruView for August 23rd.

6.0 Shark HLA/VLA

The Shark horizontal line array (HLA)/vertical line array (VLA) (Figure 6.1) was supposed to be the first instrument deployed but was actually put in last. Due to an electronics failure, it had to be refitted with a completely different motherboard and reprogrammed onboard the R/V Knorr. Even if the electronics package was in the lab, let alone on board a ship, this would have been a substantial task to accomplish in only a few days. But the refit was successfully accomplished by Keith von der Heydt and the Shark went on to record over 6 terabytes of high quality acoustics data. This delay was also bit of a blessing in disguise, since two other 'bugs' were corrected that could have ended the mission early if they had not been noticed. One was a short in a battery pack which would have stopped the Shark once it got wet and the other was a minor date-formatting problem which would have crashed the system on a new month turnover.

The shark mooring was initially planned to be deployed with the tail (end of the HLA) placed south of the electronics sled. But due to strong northernly winds, the sled/tail positions were switched so that the R/V Knorr could head into the wind while deploying this complicated mooring.

When working with the shark data, the date and time has to be scrutinized. There are times when the clocks got out of sync (see 6.3.2) and these times must be adjusted. The data header records also have some minor, correctable problems with daily turnover at midnight and date problems in the data records. These all can be identified and mended in software.

The Shark mooring information is shown in Table 22 and sampling specifications are shown in Table 23. The locations in Table 22 were checked using ship and individual log books. The surveyed positions listed below should be used for accurate locations. Section 6.3.4 discusses the surveyed positions and hydrophone localization.

Table 22: SW54 - Shark mooring configuration

SW54 Shark Mooring	
Deployed SW54 (Shark) location	39 01.2516 N 73 02.9824 W
Surveyed SW54 (Shark) location	39 01.2627 N 73 02.9887 W
Date deployed	Aug 2 14:48 (Z)
Date recovered	Sep 14 13:30 (Z)
Water Depth	79 m
Tail Deployment location 11.5kHz (xmit only)	39 01.5865 N 73 02.9833 W
Tail location -localized (no interrogation)	39 01.5831 N 73 02.9782 W
Deployed Transponder1 (West) 11kHz	39 01.3816 N 73 03.2088 W
Surveyed Transponder1 (West) 11kHz	39 01.3771 N 73 03.2107 W
Deployed Transponder2 (East) 12kHz	39 01.2420 N 73 02.5334 W
Surveyed Transponder2 (East) 12kHz	39 01.2341 N 73 02.5293 W
SW06 recovery system location	39 10.8751 N 73 02.9816 W

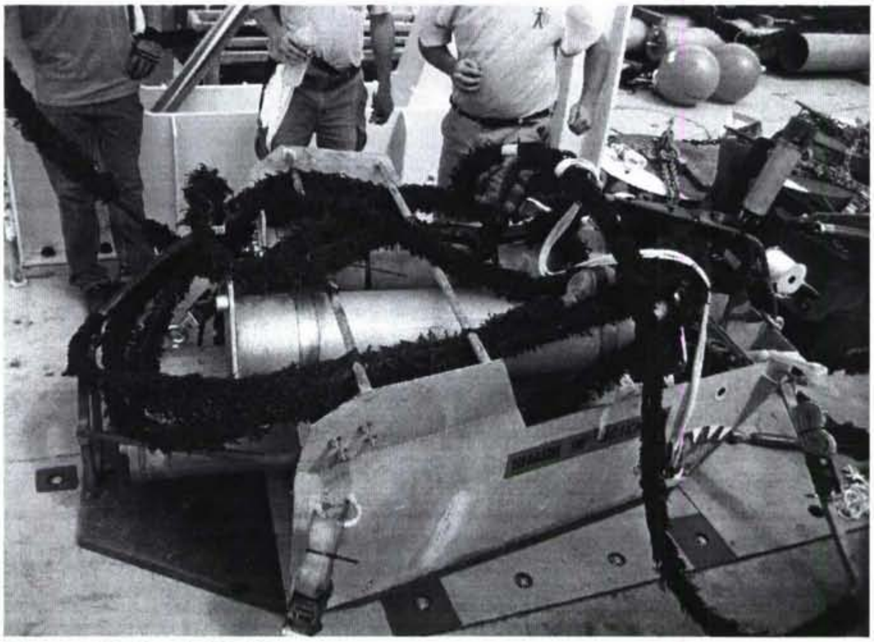

Figure 6.1: Shark HLA/VLA.

Table 23: Shark VLA/HLA specifications

Sampling rate (Hz)	9765.625 (2.5e6/256)
Number of channels (nchs)	48 (0-47)
Number of channels on Vertical Line Array (VLA)	16 (0-15)
Number of channels on Horizontal Line Array (VLA)	32 (16-47)
Number of data samples per record (nsamp)	156250
Data record length (bytes per record) (nchs*nsamp*2)	15,000,000
Trailer record length (bytes per record)	1024 bytes
Total record length	15,001,024
Number of records per file	128
Mission (battery life and data storage)	43 days
Time elapsed for 1 record	16 secs
Time elapsed for 1 file	34.133 minutes
Data file size	1,920,131,071 (~2GB)
Data storage size per day	80 GB per day
Total data storage	~4 TBytes

6.1 Shark mooring configuration

The shark Vertical Line Array (VLA) consisted of 16 hydrophones (channel numbers 0-15). Figure 6.2 diagrams the shark mooring configuration. The VLA was shortened prior to deployment since the water depth was shallower than the VLA was originally designed for. The lower hydrophones, numbers 13, 14 and 15, were wrapped together 1.25 meters above the bottom at 77.75 meters depth to reduce the length. The rest of the depth spacing can be found in Section 6.2.5.

The phone closest to the sled on the Horizontal Line Array (HLA), channel number 47, was 3 meters from the point on the sled where the VLA started. The remaining 31 phones were separated by 15 meters making the length of the HLA section 468 meters from the VLA to the last phone (channel number 16). There is 3 meters from the last phone to the HLA eye, another 125 meters of ground cable connected to that eye, and at the end was another 1.5 meters of chain connected to the tail which contained the Long Baseline (LBL) interrogator. That adds up to a total of 597.5 meters from the Shark VLA to the interrogator at the tail.

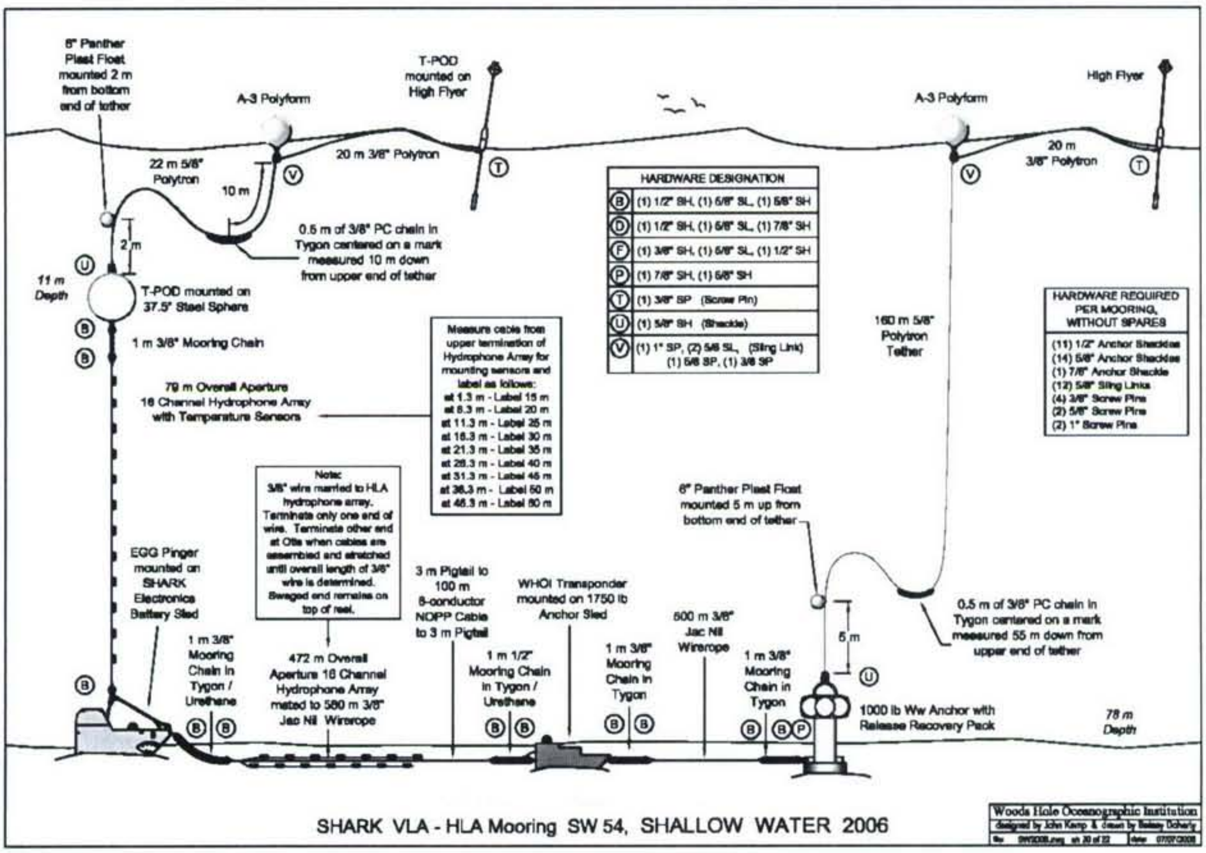

Figure 6.2 Shark mooring diagram.

6.2 Shark 48 Channel HLA/VLA data acquisition system and data format

6.2.1 System Description

A 48 channel acoustic array with recording system was deployed during SW06 for the purpose of receiving signals from multiple sources transmitting on known schedules in bands with center frequencies ranging from 75 Hz to 3,200 Hz. The system consisted of a sled housing the data acquisition system and alkaline battery packs in aluminum housings. Attached to the recording system at the sled were a 16 channel vertical array (VLA) and a 32 channel horizontal array (HLA). The system was deployed in 79 meters of water which allowed 13 of the 16 vertical array channels to span the water column from about 79 meters to 12 meter depth. The HLA was configured as 2 – 16 channel phones in series fastened to a 3/8 jacketed cable strength member. Channels are numbered from 0 through 47, with ch 0 at the top of the VLA and ch 16 at the outboard end of the HLA. The VLA section was too long for the water depth so the lower 3 hydrophones were all 1.25 meters off the seabed.

The total battery power available was nearly 49kwh assuming 20 Wh from each of 2448 alkaline D cells. The power requirement of the system in operation was about 46.5W for an estimated maximum run time of a little over 1000 hours or about 43 days.. The system was designed to record data continuously at a sample rate of 9765.625 Hz. Forty-eight analog-to-digital converters produce a 24 bit 2's complement sample that is converted on the fly to a 16 bit pseudo floating point sample as described earlier in this document to reduce the storage requirement yet preserve the dynamic range of the system. The converters are a sigma-delta configuration which includes a hardware FIR implementation of a lowpass filter/decimator structure resulting in a flat bandwidth (+/-.001 dB) of .907 * .4535 times the sampling rate or 4429 Hz.

The overall electronic signal path is as follows:

10) hydrophone with lowcut -3dB point of 10Hz and a second RC pole at about 1Hz; the high end -3dB point is about 10kHz. There is a small amount of rolloff as a function of cable length but it will not impact the reception bandwidth. The hydrophone has a built in preamplifier and current mode driver with a net sensitivity at the receiver of -170 dB re 1 μPascal. The phone output is linear up to a receive level of about 161 dB re 1 μPascal (corresponding to -9dBvrms output applied to the receiver at the recording system).
11) The recording system receiver on a per channel basis, is a dual differential design that senses the current signal across a 400 ohm load and applies a fixed gain of 21 dB with a maximum output capability of +17 dBvrms, well in excess of what the ADC can accept linearly.
12) The resultant signal is applied to the the ADC input which has max linear input of +5dBvrms (8dBVpeak).
4) The maximum acoustic RL at the phone is therefore 8 – 21 + 170 = 157 dBpeak re 1 μPa.

The system is comprised of 2 sections, the ACQstack, a PC104+ stack running Linux that powers the data acquisition side of the house and the RTC stack, a 16 bit PC104 DOS based stack that manages the time keeping and AEL chores.

6.2.2 RTC stack

The RTC stack controls the power switch for the acqstack so that if it recognizes problem conditions, the acqstack is power cycled, leading to a restart of data acquisition and the loss of about 5 minutes of data. Ideally, this should only occur at disk changes about every 1.5 days. The RTC stack consists of a 2W CPU board, an RTC/NAV board and a power control board It uses the 10 MHz rubidium oscillator as its time base to maintain accurate time using a 82C54 style counters. It maintains a logfile as well as a separate file containing the AEL information.

The primary frequency from the rubidium is 10 MHz. That is divided down to 2.5 MHz on the RTC/NAV board which is fed to an optocoupler diode on the both Serial-to-Parallel Formatter (SPF) boards at J6 (pin 1 anode, pin 2 cathode). This creates an ADC output rate of 2.5e6/256 = 9765.625 Hz

6.2.3 RTC/NAV board IO addressing, R/W:

U2

3A0 – 3A3	CLK0, 10 MHz in, /10, 1 MHz out; install BR1 pins 3-4
	CLK1 low half of 32 bit NAV counter
	CLK2 upper half of NAV counter

U3

3A4 – 3A7	CLK0, 1 kHz in, /1000, PPS out, RTC GT control;
	CLK1, 1PPS in, ALARM out, /n, ALARM GT control, use to initiate AEL epoch
	Change input to output of CLK2, set for /64000 to intr at 250 sample intervals
	CLK2, ADC Fs, 10MHz in, /1024, 9765.625 Hz out, no gate

U4

3A8 – 3AB	CLK0, 1 MHz in, /1000, 1KHz out, RTC GT control
	CLK1, RTC MSS counter, 1 kHz in, /60000, RTC ENABLE control
	CLK2, RTC MH counter, 1 min in, /1440, RTC ENABLE control

3B8, W bit 0	AEL CH select lsb, M0

6.2.5 Interrupt operations:

U3-T0 PPS, at the 16s interval, sends a "*mm dd yyyy hh nn ss.uuuuuu total_rec#" string to ACQSTACK and waits 8 seconds for serial string ACK from ACQSTACK. The ACQSTACK ACK string consists of:
*mm dd yyyy hh nn ss filename rec#_in _file tag_byte_1st_sample_this_record

At the 1800 second (30 minute) interval on the hour and 360 seconds (6 minutes) after this interval, the Shark performs array element localization operations. The sequence of events is: 1) the RTC stack fires the HLA tail interrogator, a 10ms 11.5kHz pinger; 2) 7 channels, 0, 6, 10, 13, 17, 27 & 37 are cycled through the detector hardware at a 7s interval to allow travel time measurements from the interrogator, and 2 transponders at 11.0 and 12.0 kHz. The travel times are logged by the RTC system with microsecond resolution at the end of the 49 second cycle. These same data are sent to the ACQ system which logs them as well.

The 11.5 kHz 10ms pings occur without delay from the RTC system time as they are initiated electronically via an opto coupler, hence the travel times measured require no correction. The 11.0 and 12.0 kHz receptions are 2-leg travel times as they represent the time of flight from the 11.5kHz interrogator to the transponder as well as from the transponder to the selected hydrophone. The turnaround time of the TR6000 Benthos transponder is specified to be 3ms. There is also the time of integration of the 10ms pulse to detect it so the total "travel time" is the flight time from interrogator to transponder, flight time from transponder to array phone, 3ms + ~10ms.

The same is true of the EG&G CART, used in place of an 11.0kHz TR6000 but it has a total turnaround time plus detection delay spec of 12.5 ms.

6.2.6 ACQ stack

The Linux stack (acqstack) acquires data from a set of 6 8-channel ADC's via a pair of formatting boards that each convert the serial bit streams from 24 channels and combine into a single stream of 32 bit words that consist of the 24 bit ADC word plus a diagnostic tag byte. The word stream is FIFO buffered by a digital IO board (DIO) that transfers data to main memory via DMA. The ADC and formatter boards were previously designed for another project at WHOI.

The acqstack runs RedHat 7.2 for a number of reasons related to a nonstandard mix of hardware and the driver for the DIO board. A required feature is journaling (EXT3 filesystem) so that the stack can be power cycled at will. As it is, it takes about 5 minutes for the acqstack to boot from power up..

The data acquisition component consists of a PC104+ stack comprised of, starting at the bottom, 2 SPF boards, a Lippert 300 Mhz CPU board, a PCI adapter board and a DIO board. This is essentially the same as the original SPACE project stack with the addition a 2^{nd} SPF board to accommodate 2 – 24 ch ADC groups. The data storage rate with 48 ch is therefore (2.5e6/256) * 2bytes/sample * 48ch * 3600s/h = 3.375e9 b/hour, 937,500 b/s not including record headers, 1024 bytes each

Data are stored in files of 1.920,131,072 bytes consisting of 128 records. Each record ends in a 1024 byte trailer. A record constitutes 16 seconds of data and data are seamless across records and files, with the exception of disk changes when approximately 5 minutes of data will be lost due to power cycling of the ACQstack. A 16 second record consists of 156,250 groups a sample from each of 48 channels. A new file will be started every 2048 seconds. The channel mapping given that the first channel in a file is considered file CH 0 and corresponds to array CH 1 is:

CH# in file	CH# in array	Physical position in array	Phone depth (m)
24	0	VLA, top	13.5
0	1	VLA	17.25
25	2	VLA	21.0
1	3	VLA	24.75
26	4	VLA	28.5
2	5	VLA	32.25
27	6	VLA	36.0
3	7	VLA	39.75
28	8	VLA	43.5
4	9	VLA	47.25
29	10	VLA	54.75
5	11	VLA	62.25
30	12	VLA	69.75
6	13	VLA	77.25
31	14	VLA	77.75
7	15	VLA	77.75
			Est distance from sled
32	16	HLA, tail	468
8	17	HLA	453
33	18	HLA	438
9	19	HLA	423
34	20	HLA	408
10	21	HLA	393

35	22	HLA	378
11	23	HLA	363
36	24	HLA	348
12	25	HLA	333
37	26	HLA	318
13	27	HLA	303
38	28	HLA	288
14	29	HLA	273
39	30	HLA	258
15	31	HLA	243
40	32	HLA	228
16	33	HLA	213
41	34	HLA	198
17	35	HLA	183
42	36	HLA	168
18	37	HLA	153
43	38	HLA	138
19	39	HLA	123
44	40	HLA	108
20	41	HLA	93
45	42	HLA	78
21	43	HLA	63
46	44	HLA	48
22	45	HLA	33
47	46	HLA	18
23	47	HLA, sled end	3

There are 2 SPF boards and each must be configured via 8 bit IO (as root) to specify board ID's and 24 channels . The first 24 channels are handled by BOARD 0 (upper board in stack) which must have its 2 BRD_SEL lines at 00 and its CH_SEL lines at 10 to specify 24 active channels. The 2[nd] SPF board must have its BRD_SEL lines at 01 and its CH_SEL lines at 10. Both boards must have the MD_SELECT line HI to specify that the FSA clock is the ADC clock rather than the sample rate. The ADC clock is 256 * sample rate.

The SPF control port bits are:

	SPF-0 board (IO address 0x300)	SPF-1 board (IO address 0x310)
Bit 0	0	0
Bit 1	0	0
Bit 2	0	0
Bit 3	0	0
Bit 4	1	1
Bit 5	1	1
Bit 6	0	1
Bit 7	0	0

Operational methodology for the Linux ACQ system is:

1- System boots, either from power cycling or warm boot

2 - If power cycle, DISK0 will be running, else if warm boot, last disk selected will be running

3 - Send ACK "*month,day,year,hour,min,sec,tag-byte,recnum,filenum" to RTC/NAV system on serial port

4 – Run acq code

5 - Config SPF ports, wait for data and store as it becomes available

6 – At 156,250 sample boundaries, write record header, continue writing samples as available
7 - Monitor serial port for date/time and AEL info, install in current record header template as available
8 – ACK RTC/NAV system over serial port after reception of each TIME/NAV string (every 16 s)
9 – Note modulo 256 count in record header at end of each record
10 - Terminate files at 128 record intervals & start next file seamlessly
11 - Create filenames consisting of date/time
12 - Keep separate file of serial transmissions data as well as embedding it in the record headers

Format of date/time info from RTC/NAV system to ACQ, GMT date/time

ASCII string, comma delimited
*MM DD YYYY HH NN SS.uuuuuu rrrrr<CRLF>
(* specifies new time string)
MM month 1 – 12
DD day 1 – 31
YYYY year, 2006
HH hour 00 - 23
NN minute 00 – 59
SS seconds 00 – 59
uuuuuu fractional seconds in microseconds
rrrrr is record count on current disk from last ACQSTACK boot

6.2.7 Format of AEL information from RTC/NAV system

A space delimited ASCII string, with up to 4 receptions per each of 3 frequencies per each of the 7 LBL channels, is stored in a log file and in the data header. Each received time delay is reported in microseconds. The period of AEL epochs is every 1800 seconds (30 minutes) on the hour and 360 seconds (6 minutes) after each 1800s mark. During an AEL epoch, the interrogator at the HLA tail pings and a channel in the sequence (0-top of VLA, 6, 10 13 (bottom of VLA), 17 (2nd HLA channel in from the far end and 144.5 meters from the interrogator) 27 and 37 are sequentially connected to the transformer coupled input of the Sonatech tone detector board for a period of 7 seconds. Detection pulses at each of the 3 frequencies for each channel are applied to an interrupt circuit on the RTC system. Delay values could be from about 100,000 to 2e6 microseconds. Up to 4 detections at each frequency will be logged to assist in sorting out the multipath structure.

The logged data format is a sequence blocks that contain a line marking the date and time of the reception followed by 21 lines of the 4 receptions per line for each channel and transmitted frequency. The format is as follows:

@MM DD YYYY HH NN SS.uuuuuu RRRR... SSSS....
ch00_d110.1 ch00_d110.2 ch00_d110.3 ch00_d110.4
ch00_d115.1 ch00_d115.2 ch00_d115.3 ch00_d115.4
ch00_d120.1 ch00_d120.2 ch00_d120.3 ch00_d120.4
ch06_d110.1 ch06_d110.2 ch06_d110.3 ch06_d110.4
ch06_d115.1 ch06_d115.2 ch06_d115.3 ch06_d115.4
ch06_d120.1 ch06_d120.2 ch06_d120.3 ch06_d120.4
ch10_d110.1 ch10_d110.2 ch10_d110.3 ch10_d110.4

ch10_d115.1	ch10_d115.2	ch10_d115.3	ch10_d115.4
ch10_d120.1	ch10_d120.2	ch10_d120.3	ch10_d120.4
ch13_d110.1	ch13_d110.2	ch13_d110.3	ch13_d110.4
ch13_d115.1	ch13_d115.2	ch13_d115.3	ch13_d115.4
ch13_d120.1	ch13_d120.2	ch13_d120.3	ch13_d120.4
ch17_d110.1	ch17_d110.2	ch17_d110.3	ch17_d110.4
ch17_d115.1	ch17_d115.2	ch17_d115.3	ch17_d115.4
ch17_d120.1	ch17_d120.2	ch17_d120.3	ch17_d120.4
ch27_d110.1	ch27_d110.2	ch27_d110.3	ch27_d110.4
ch27_d115.1	ch27_d115.2	ch27_d115.3	ch27_d115.4
ch27_d120.1	ch27_d120.2	ch27_d120.3	ch27_d120.4
ch37_d110.1	ch37_d110.2	ch37_d110.3	ch37_d110.4
ch37_d115.1	ch37_d115.2	ch37_d115.3	ch37_d115.4
ch37_d120.1	ch37_d120.2	ch37_d120.3	ch37_d120.4

6.2.8 Acoustic Array Data Format

The data are stored in a 16 bit pseudo floating point format identical to that used for a prior deployment during the ASIAEX experiment [1]. Date records and files are similar though not identical to those in the ASIAEX data set. They are longer and the data record headers are written as the last 1024 bytes of a record.

A data file is a contiguous sequence of records, each ending with a 1 Kbyte data record header (DRH), in which the record number, time of the first sample in the record to the microsecond, record size, number of channels, and the "occasional" acoustic navigation data are identified. Data records will be 10 sec (~10 MByte) in length. The navigation information will be partitioned according to the update rate in a format yet to be determined. Other DRH information will be constant throughout the file. Following each DRH will be multiplexed data. A data record containing VLA & HLA data will be of the following form:

FOR SW06 data:

VLA chan 0 value, chan 1 value, chan 2 value,....... VLA chan 47 value,
VLA chan 0 value, chan 1 value, chan 2 value,....... VLA chan 47 value,
VLA chan 0 value, chan 1 value, chan 2 value,....... VLA chan 47 value,
"
"
"
VLA chan 0 value, chan 1 value, chan 2 value,....... VLA chan 47 value,
DRH <1024 bytes>

EOF

Data will be stored as unsigned short int (2 bytes), with the lower byte occurring first followed by the upper byte. The bits are high true, i.e an active bit is a ``one " or high logic level. The 16 bit sample consists of a 14 bit, 2's complement mantissa (M12 is msb), in the low part of the word with the 2 gain bits in the lower part, (G1 is msb). The sign bit is in the 15th bit position. Bits 0 through 7 are the

```
Bit 15   14   13   12   11   10   09   08   07   06   05   04   03   02   01  00
    SN  M12 M11 M10 M09 M08 M07 M06 M05 M04 M03 M02 M01 M00  G1 G0
    {+/-}{          13 BIT MANTISSA                           }{GAIN}
```

The 4 gain bit combinations indicate the number of 3 bit right shifts that must be applied to the mantissa to recreate the 24 bit ADC word.

00 -> no right shift of 14 bit mantissa required
01 -> mantissa must be right shifted 3 bits
10 -> mantissa must be right shifted 6 bits
11 -> mantissa must be right shifted 9 bits

Recreated 24 bit ADC word; bit 23 is the sign bit, 2nd row bits are from the stored 16 bit word, unused bits (--) assume sign bit value

```
GAIN bits = 00  (largest values)
23 22 21 20 19 18 17 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01 00
15 14 13 12 11 10 09 08 07 06 05 04 03 02 --  --  --  --  --  --  --  --  --  --

GAIN bits = 01
23 22 21 20 19 18 17 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01 00
15  --  --  --  14 13 12 11 10 09 08 07 06 05 04 03 02  --  --  --  --  --  --  --

GAIN bits = 10
23 22 21 20 19 18 17 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01 00
15  --  --  --  --  --  --  14 13 12 11 10 09 08 07 06 05 04 03 02  --  --  --  --

GAIN bits = 11 (smallest values)
23 22 21 20 19 18 17 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01 00
15  --  --  --  --  --  --  --  --  --  14 13 12 11 10 09 08 07 06 05 04 03 02  --
```

One method of normalizing the stored 16 bit integer Shark data to a value of volts from the hydrophone is this:

```
exp =  val[i] & 0x0003
gain = 10^(21/20) * 2^(exp*3)
voltage (at hydrophone output) = (((val[i] >> 2) / 8192) * 2.5v) / gain
```

A second method perhaps more convenient when data are brought into Matlab for processing, is to read the data as 16 bit shorts. Data will become doubles in Matlab. The gain normalizing algorithm is below. The divisor of 11.2 accommodates the Shark ADC fixed gain of 21 dB

```
data=data/4;
mantissa=floor(data);
gain=4*(data-mantissa);
gain=(2*(ones(1,BLKSIZE))).^(3*gain);
```

voltage=(2.5)*((data)./gain)/8192/11.2;

Peak to peak voltage at the output of a phone is 1Vpp. (Vpp = -9 dBv). Since the Shark hydrophone sensitivity is nominally 170 dB re 1 μPa per 1 volt, to convert the data time series, after normalizing as described above, from volts to microPascals (μPa) is:

$$\mu Pa = voltage * 10^{(170/20)}$$

Standard processing procedures can be performed in either microPascals or volts. The conversion of dB levels from volts to microPascals is:

$$\text{dB re 1 } \mu Pa = \text{dB re 1 volt} + 170$$

There will be 156,250 values for all channels in a record. Following the last sample suite of a record, will be the Data Record Trailer (DRT) for that record, followed by the first sample suite of the next record. Time to the microsecond of the first sample in any record and the record number are recorded in the record header as shown in the "C structure" used to define the 1024 byte DRT. This value generally is about 1-2ms high due to the interrupt response time of timing of the RTC system. The DRT structure:

Note that for Shark data, the time information in bytes 8 – 13 should be used. The date information in bytes 736-737 should be used and the record number information for the current file in bytes 760-761 or total records on the current disk in bytes 14-15 can be used. After 6 occasions of data loss due to inability of the ACQ system to keep up during execution of an unexpected weekly cron job (linux scheduler) , only the current file record number will be correct in the DRH.

Note that the yearday in the Shark data record header (DRH) lags the filename yearday tag (first 3 digits) by 3 days. The filename date is correct. The yearday in the DRH should not be used.

If the data was recorded from one day to the next past midnight, the day did not not get incremented until the next new file was created. The day rollover increment will have to be incorporated into the software that reads the DRH. This has not been done to date.

```
struct data_rec_h                              // 1024 bytes total        (DRT bytes)
{
        unsigned char  rhkey[4];               // header key, "DATA"    (0-3)
        unsigned int       date[2];            // RTC  date[0]=year, date[1]=Year-day#   (4-7)   (yearday not accurate)
        unsigned int       time[2];            // RTC  time[0] = (hours*60 + minutes)     (8-11)
                                               // RTC  time[1] = (seconds*1000 + milliseconds)
        unsigned int       microsec;           // RTC  microseconds, from RTC/AEL system  for Shark   (12-13)   unsigned int
        rec;                                   // RTC  this record #       (14-15)

        int                ch;                 // # channels         (16-17)
        char               unused1[2];         // (18-19)
        long               npts;               // # sample periods per record, 156250 for Shark   (20-23)
        float              rhfs;               // sample rate in Hz <9765.625> ,  937500 B/s      (24-27)
        long               rectime;            // record time in microsec <16,000,000>      (28-31)
```

```
                                        // 128 recs* 15,001,024 B/rec = 1,920,131,072 bytes per file
char            rhlat[16];              // long, ascii DDD MM SS.T N or S, for SW06 N/A  (32-47)
char            rhlng[16];              // long, ascii DDD MM SS.T E or W, for SW06 N/A  (48-63)

unsigned long   nav120[7][4];           // for Shark LBL nav, 112 bytes  (64-175)
unsigned long   nav115[7][4];           // for Shark LBL nav, 112 bytes  (176-287)
unsigned long   nav110[7][4];           // for Shark LBL nav, 112 bytes, total 336 bytes  (288-399)

char            POS[128];               // MOMAX4 POS string for lat/long  (400-527)
char            unused2[208];           // (528-735)

int             nav_day;                // date/time of this LBL suite  (736-737)
int             nav_hour;               // (738-739)
int             nav_min;                // (740-741)
int             nav_sec;                // (742-743)
int             lblnav_flag;            // indicates that lbl data is valid  (744-745)
char            unused3[2];             // for SHRU, 625,000 for MOMAX4  (746-747)
long            record_length;          // record length in bytes; 15,001,024 for Shark, 1,251,024
                                        // for SHRU  (748-751)
int             acq_day;                // (752-753)     ACQSTACK day
int             acq_hour;               // (754-755)     ACQSTACK hour
int             acq_min;                // (756-757)     ACQSTACK minute
int             acq_sec;                // (758-759)     ACQSTACK second
int             acq_recnum              // record count from ACQ system  (760-761)
int             ADC_tagbyte             // tag byte of first sample in this record  (762-763)
int             glitch_code;            // if glitch this record, non-zero=type  (764-765)
int             boot_flag               // if this first rec after boot, this byte=0xff, else 0x00  (766-767)

char            internal_temp[16];      // N/A  for SW06, temp for MOMAX & SHRU  (768-783)
char            bat_voltage[16];        // SW06, Vmain for MOMAX & SHRU  (784-799)
char            bat_current[16];        // N/A  (800-815)
char            status[16];             // (816-831)
char            proj[16];               // project name, <SW06 > (832-847)
char            aexp[16];               // (848-863)
char            vla[16];                // <PHONE SENS -170>  (864-879)
char            hla[16];                // < -170 >  (880-895)
char            fname[32];              // ascii file name  (896-927)
char            record[16];             // ascii representation of RTC rec #, REC ####  (926-943)
char            adate[16];              // ascii representation of RTC date, mo/da/yr  (944-959)
char            atime[16];              // ascii rep of RTC rec time, hr:mn:ss.mmmmmm  (960-975)

long            file_length;            // 128 record file len, Shark, 1,920,131,072 bytes  (976-979)
                                        // 128 record file len, SHRU, 160,131,072 bytes
                                        // 128 record file len, MOMAX4
long            total_records           // total # records to date  (980-983)
char            unused4[2];             // (984-985)
int             adc_mode;               // 0 =fixed point, 1 = 24 bit, <2 = pfp>  (986-987)
int             adc_clk_code;           // ADC clock timebase divider, Shark=4, SHRU=1  (988-989)
char            unused5[2];             // (990-991)

long            timebase;               // 10 MHz rubidium  (992-995)
```

```
        char            unused6[12];            // (996-1007)

        char            unused7[12];            // (1008-1019)
        char            rhkeyl[4];              // end of rec header key "ADAT"   (1020-1023)
} ;
```

6.2.9 Shark OPS and clock sync

The Shark deployment started at 14:30Z on 2 Aug and was completed approximately at 16:35Z. Depth at the Shark sled was measured at 79 meters using sound speed of 1500 m/s. The actual sound speed was more like 1515-1520, so depth was probably more like 80m. The VLA top float was at 11.0 meters depth and had a diameter of 1 meter. The system was started at 12:05:36 on 08/02/2006 and, at that time, the Shark clock time lagged GPS time by 9.4 microseconds.

The Shark was recovered 14 Sept 2006 at approx 1330Z. The battery voltage was 22 and the Shark time lagged GPS PPS by 740 microseconds. The time was indeed synchronized to GPS, however,the date of the RTC stack was 8 Aug. It has been determined that a software bug was the cause of the incorrectly incrementing date and was due to the accommodation of a RTC CPU failure prior to deployment using a spare CPU that was not identical to the originally installed unit. The system was, at the time of recovery, writing data to the last disk in the stack of 31 data disks. Subsequently, it was found that disk 0 of PACK 1 was unused due to an incorrect identified on that disk which is responsible for a 16 hour gap. There are a number of breaks in the data stream, specifically about 30-31 minute GAPS at disk changes which occurred about every 34.13 hours. In addition, there are a number of shorter data gaps that occurred over the course of the deployment due to apparent RTC system watchdog reboots which in turn caused reboots of the acquisition system. There are 6 instances where the ACQ system responded to weekly or in one case a monthly cron job that we failed to defeat, which caused data buffer overruns resulting in a mismatch in record number between the ACQ system and the RTC system. In all 6 cases, the time offset has been recovered, allowing the data in those periods to be used by correcting the time reported in the date record trailer for the remainder of the day after the buffer overflow occurred. The specific times of these anomalies have been tabulated on an accompanying spread sheet and are shown below. The stability of the sampler clock and the RTC system including the times written in data header records are accurate to the stability of the rubidium oscillator.

6.3 Shark data

6.3.1 Shark acoustic data and data filename convention

The quality of the acoustic data acquired by the Shark was, not surprisingly, extremely good. Over 4 terabytes of data was saved. Figure 6.3 shows a typical spectrogram from the Shark VLA (channel 7). Nine different receptions centered around frequencies 50Hz, 125Hz, 175Hz, 224Hz, 300Hz, 400Hz, 500Hz, 800Hz, and 1600Hz are easily seen. Figure 6.4 shows a spectrogram from the HLA (channel 21). Low frequency LFM and CW signals are clearly seen in this image.

As described above (Table 23), each Shark data file contains 34.13 minutes of continuous data and has an ~1.9 GB file size. Each file contains 128 16-sec records. There is no timing skew between channels within each record in the file; all 48 channels have the exact same start times. The file naming convention used by the Shark is as follows:

DDDhhmmss.dat

where DDD is the Julian day (Jan. 1st at noon is 1.5 Julian), hh is the hour, mm is the minute, and ss is the second of the beginning record of that data file.

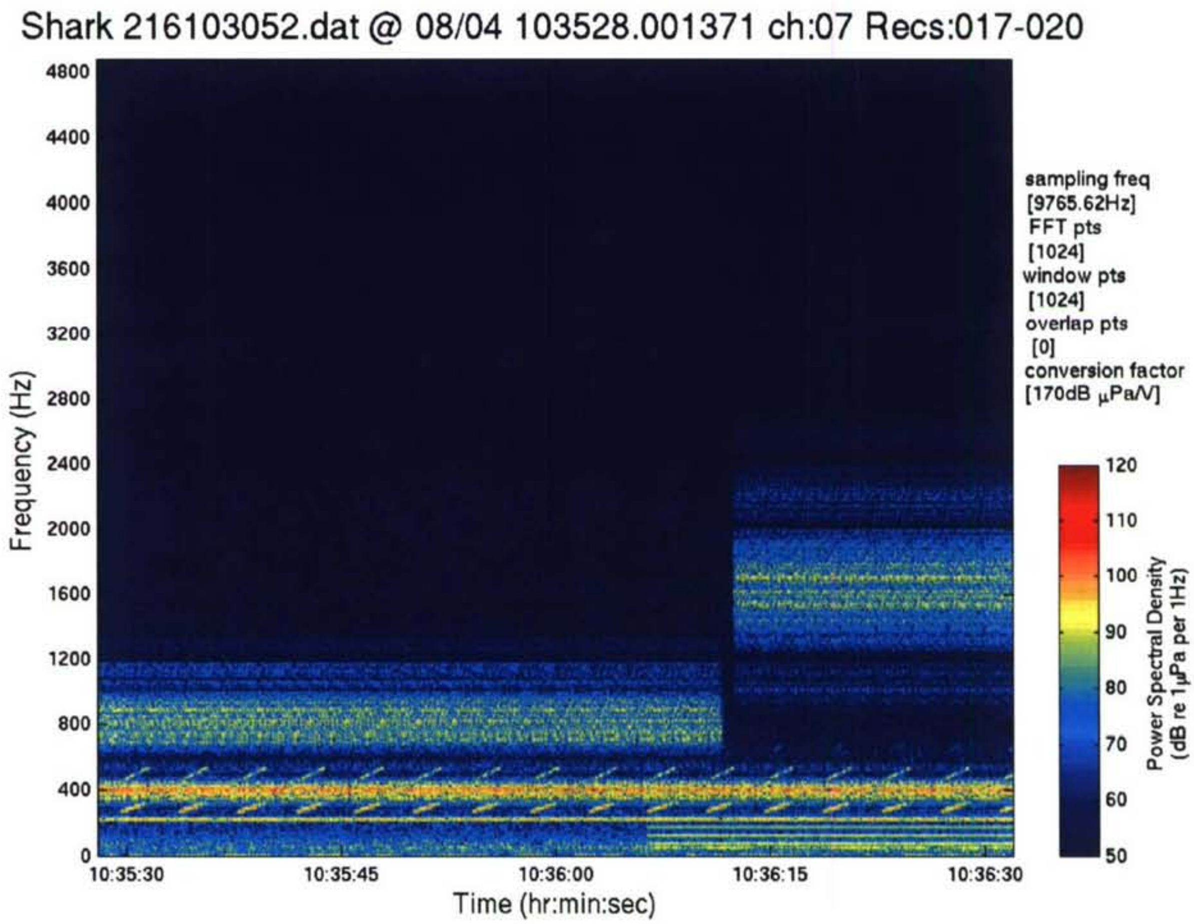

Figure 6.3 Spectrogram from channel 7 on the Shark VLA.

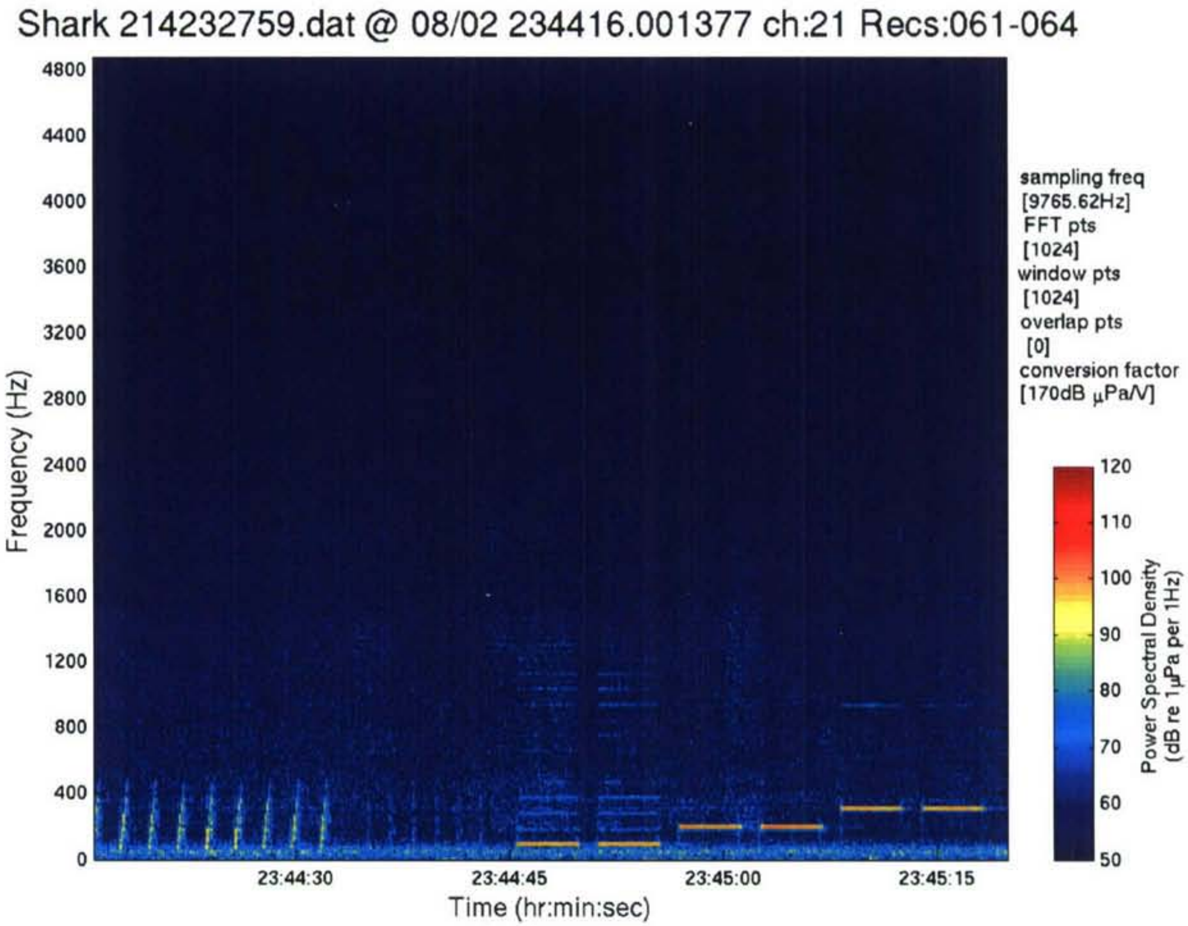

Figure 6.4 Spectrogram from Shark HLA.

6.3.2 Shark Clock latency

The timing that drives the sampling is done strictly in hardware, exact, and causes the interrupt that marks the start of a record as a function of the 16 second record period. The time keeping that is saved in the record header is performed by an internal clock. Since there may be some time latency between the time of the interrupt and a clock check, a <25 microsecond jitter can sometimes be seen in the time stamped in the record header (Figure 6.5). This jitter does not exceed the 102.4 microsecond sample period and, when creating a long time series, can be addressed by 1) choosing the minimum or median time from the microsecond time stamp in the record header or 2) use the time at the start of the time series and calculate the exact time series using the sampling frequency. If a restart occurs in the data, this process will have to be started again (Figure 6.6). There is no time latency between channels.

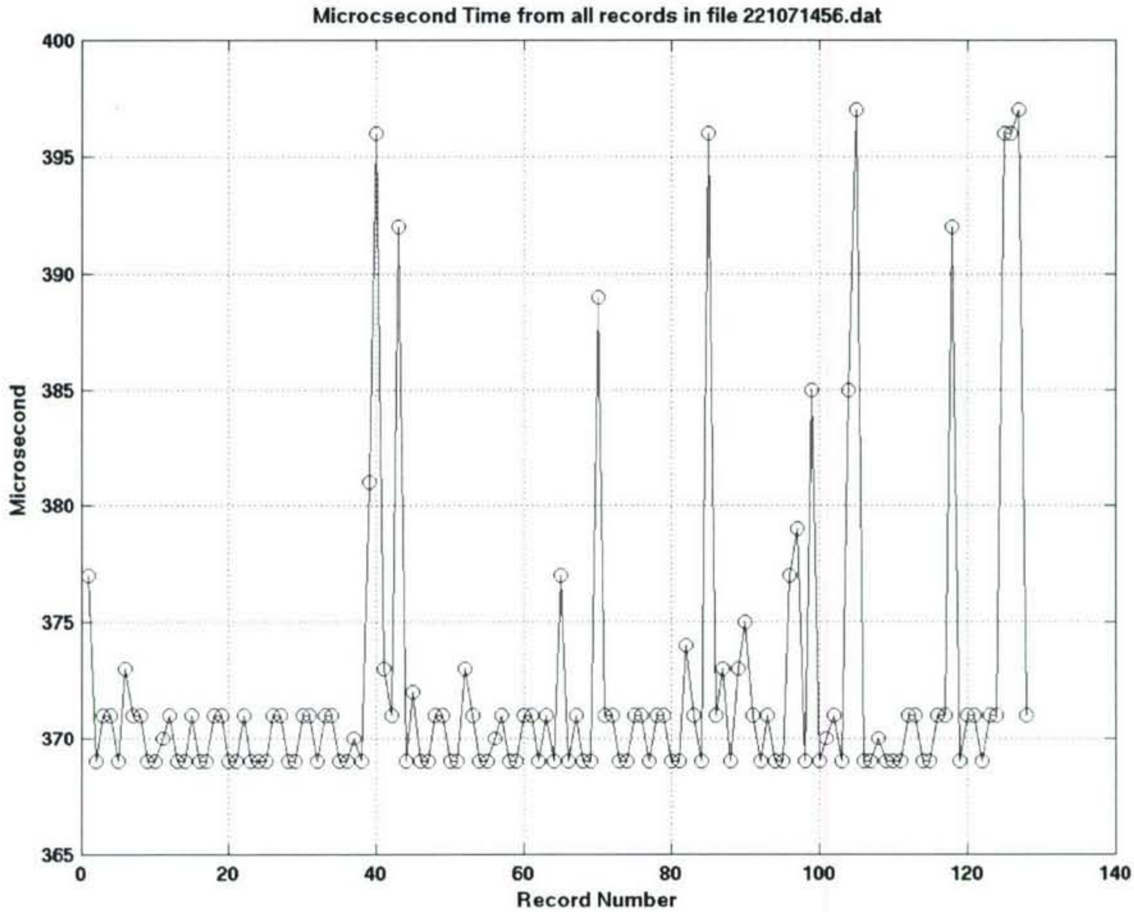

Figure 6.5 Plot of time 'jitter' in microsecs from Shark header records. In this case, the 'exact' time in microsecs should be 370 microseconds.

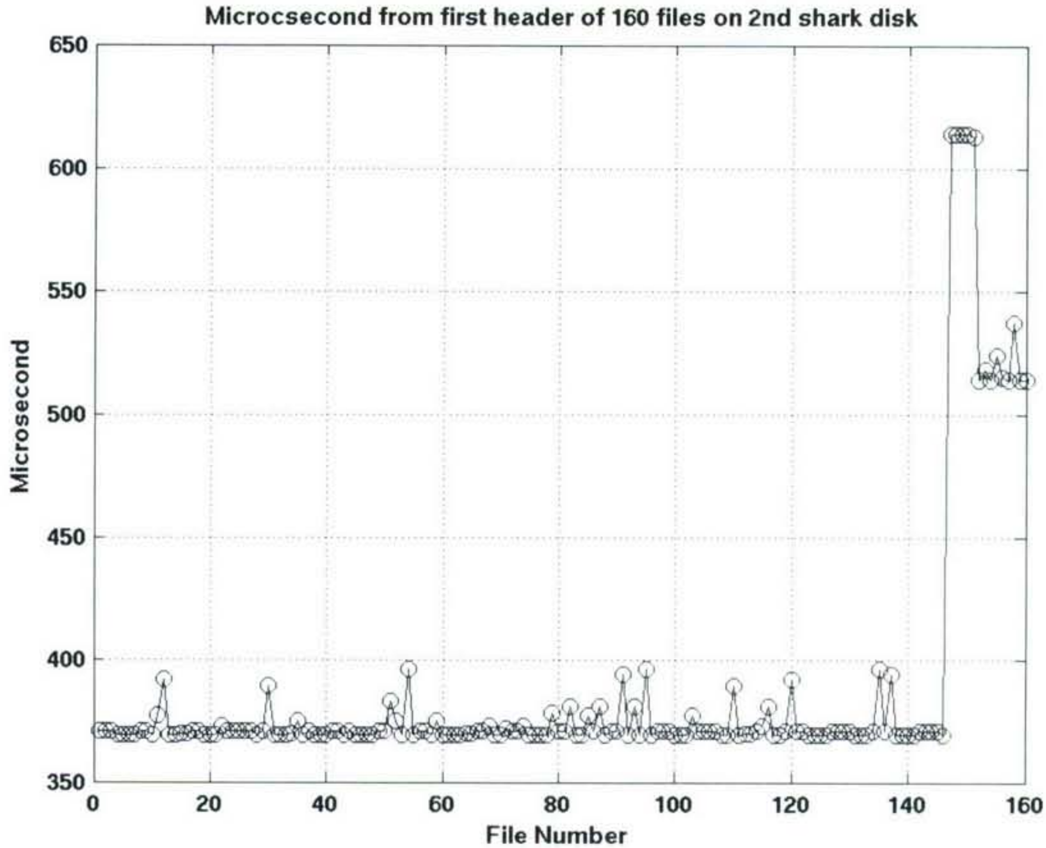

Figure 6.6 Plot of time 'jitter' in microsecs from first Shark header record in consecutive files. Notice that 1) jitter will have to be addressed from file to file and 2) recalculated when a restart occurs as in files #148 and #156 here.

6.3.3 Timing problems

Gaps and time corrections in Table 24 are for 6 events in the SW06 Shark data set that occurred as a function of cron job problems. Linux Operating systems, like the one used for the Shark, uses the cron application to execute scheduled commands. There were 6 regions in the apparently continuous data where some data loss occurred. The gaps specified below are regions where multiple 1.6 sec buffers were not logged due to unexpected Linux cron jobs that temporarily pre-empted the data acquisition process. The correction specified is time in seconds to be subtracted from the time reported in bytes 8 - 13 in the 1024 byte record trailer in order to correctly specify the actual start time of data records subsequent to the region of loss. The correction times are exact due to the constant and known length of data buffers and the known sequence in which they were acquired and logged. Note, the time reported in bytes 8 - 13 is from the time keeping portion of the Shark system. The day number should be taken from bytes 752-753; record number in the current file (0-127) should be taken from bytes 760-761. Be careful to note that day rollover in bytes 752-753 may not occur in sync with the correct time in bytes 8-13 but may have to be "manually" synchronized because the time in bytes 8-13 is correct. Table 24 lists the files and records where data has been lost and those records where good data starts but with a time adjustment. Tables 25-29 list those files that contain good data but have times that must also be adjusted. Day 247 had only 1 file that was affected so no table was created for that day. More information about timing is documented in Section 6.2.

Table 24: Shark data corrections to gaps due to cronjob (scheduling) problems. Note: the reason for the apparent mismatch between regions of data loss and the duration of the gap is that the record number was not incrementing during this gap.

Data FILE	Region of Data loss (header record #s)	Duration of data gap in seconds	correction to time reported in bytes 8-13 of 1024 byte trailer for subsequent data records (see affected files below)
218035622.dat after R4340	R4321 – R4340	614.400 s	subtract 9.600s from time reported after R4340
232041228.dat after R6456	R6436 – R6456	570.400 s	subtract 9.600s from time reported after R6456
239043124.dat after R5505	R5486 – R5505	614.400 s	subtract 9.600s from time reported after R5505
246041208.dat after R58	R35 – R58	729.600 s	subtract 6.400s from time reported after R58
247072302.dat after R2830	R2830	28.800 s	subtract 3.200s from time reported after R2830
253040845.dat after R3528	R3506 – R3528	649.600 s	subtract 6.400s from time reported after R3528

Table 25: Shark data files during Day 218 that need time adjustment.

Files that need data time adjustment for Day 218 - Aug 6, 2006 -9.6 seconds				
218043525.dat	218050932.dat	218054341.dat	218061749.dat	218065155.dat
218072604.dat	218080012.dat	218083420.dat	218090828.dat	218094236.dat
218101644.dat	218105051.dat	218112459.dat	218115907.dat	218123315.dat
218130723.dat	218134131.dat	218141539.dat	218144946.dat	218152355.dat
218155802.dat	218163211.dat	218170619.dat	218174025.dat	218181434.dat
218184842.dat				

Table 26: Shark data files during Day 232 that need time adjustment.

Files that need data time adjustment for Day 232 - Aug 20, 2006 -9.6 seconds				
232045131.dat	232052539.dat	232055947.dat	232063354.dat	232070802.dat
232074210.dat	232081618.dat	232085026.dat	232092434.dat	

Table 27: Shark data files during Day 239 that need time adjustment.

Files that need data time adjustment for Day 239 - Aug 27, 2006 -9.6 seconds				
239050559.dat	239054007.dat	239061415.dat	239064824.dat	239072231.dat
239075639.dat	239083046.dat	239090454.dat	239093902.dat	239101311.dat
239104718.dat	239112126.dat	239115535.dat	239122942.dat	239130350.dat
239133757.dat				

Table 28: Shark data files during Day 246 that need time adjustment.

Files that need data time adjustment for Day 246 - Sep 3, 2006 -6.4 seconds				
246045204.dat	246052612.dat	246060018.dat	246063427.dat	246070834.dat
246074243.dat	246081651.dat	246085058.dat	246092506.dat	246095914.dat
246103322.dat	246110729.dat	246114137.dat	246121546.dat	246124954.dat
246132401.dat	246135809.dat	246143217.dat	246150625.dat	246154032.dat
246161440.dat	246164848.dat	246172257.dat	246175704.dat	

Table 29: Shark data files during Day 253 that need time adjustment.

Files that need data time adjustment for Day 253 - Sep 10, 2006 -6.4 seconds				
253044734.dat	253052142.dat	253055549.dat	253062958.dat	253070406.dat
253073813.dat	253081221.dat	253084629.dat	253092037.dat	253095446.dat
253102854.dat	253110301.dat	253113708.dat	253121116.dat	253124524.dat
253131933.dat	253135341.dat	253142747.dat	253150156.dat	253153604.dat
253161011.dat	253164420.dat	253171828.dat	253175235.dat	253182643.dat
253190050.dat	253193459.dat	253200906.dat	253204315.dat	253211723.dat
253215130.dat	253222538.dat			

6.3.3 Environment sensors on the Shark mooring – SW54

A number of temperature sensors and one temperature/pressure sensor were attached to the VLA to get a time series of the temperature at the Shark mooring. Table 30 lists those sensors. Figure 6.7 shows an image of the temperature time series taken at the Shark VLA.

Table 30: Environment sensors on SW54 – Shark mooring.

Sensor	Sensor Number	Depth (m) at deployment depth (79m)	Sampling interval (secs)	Notes
Tpod	2048	1	30	Lost
SBE39	242	13	30	T/P quit early
Tpod	2047	15	30	
SBE39	22	19	30	
Tpod	2051	22	30	
SBE39	23	26	30	
Tpod	2096	34	30	
Tpod	2097	41	30	
Tpod	2094	56	30	
Tpod	2095	71	30	
Tpod	2062	79	30	

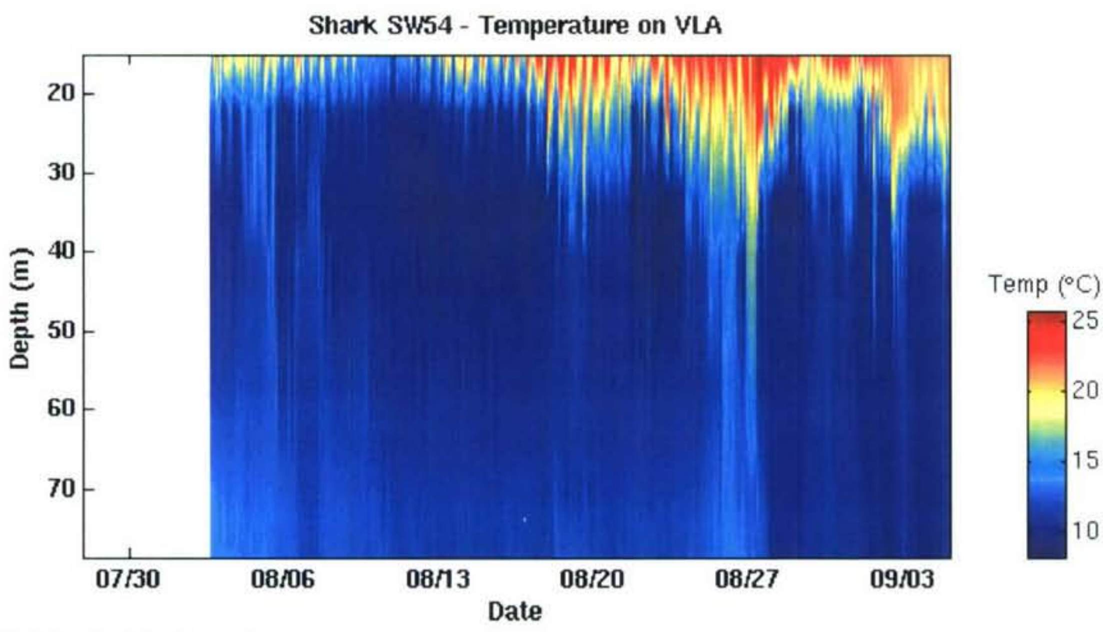

Figure 6.7 SW54 – Shark mooring temperature record.

6.3.4 Mooring motion and hydrophone localization

An acoustic long baseline (LBL) array navigation system was used for tracking the Shark mooring's horizontal line array (HLA) and the vertical line array (VLA). Four channels on the VLA and three channels on the HLA were used to detect LBL high-frequency (11kHz, 11.5kHz, and 12kHz) signals. These signals were stored as LBL path travel times which are then used for hydrophone localization. Table 31 lists the channels used for the LBL system. Data format and other specific LBL information are described in Section 6.2.7.

Table 31: Designated LBL channel numbers for the Shark.

Channel Number	*Depth/Distance (meters)*	*Comments*
0	13.5	VLA (Top of mooring)
6	36.0	VLA (using ref: shark @ 79m)
10	54.75	VLA (using ref: shark @ 79m)
13	77.25	VLA (using ref: shark @ 79m)
17	453	HLA (distance from body of shark)
27	303	HLA (distance from body of shark)
37	153	HLA (distance from body of shark)

The Shark HLA/VLA, west transponder, and east transponder were all acoustically surveyed after deployment and exact positions were calculated using ray traces to identify ray paths and a least squares method for computing the localization. Positions of the shark elements and LBL geometry, corresponding to the surveyed positions (Table 22), are shown in figure 6.8. An interrogator was located at the HLA tail and was scheduled to transmit an 11.5kHz signal 4 times an hour at 0, 6, 30 and 36 minutes. This signal was received directly on the HLA and VLA LBL hydrophones. This 11.5kHz signal was also received by the east and west transponders which would then transmit an 11.0kHz and 12.0kHz signal, respectively, and would complete the LBL travel time paths from the tail to the HLA/VLA (see Section 6.2.7). During transponder receive/transmit processing, a 12.5 millisecond turnaround delay time must also be included to the travel times of those paths.

The physical length of the HLA from the Shark sled to the HLA tail was 597.5 meters. Since the interrogator in the HLA tail only transmitted, no precise acoustic location survey was performed, but instead LBL transmissions on August 2nd (after deployment) and on September 6th (before recovery) were chosen to calculate its position. Both day's LBL data converged to the same point within 1 meter accuracy. The computed distance from Shark to tail was 593 meters which indicates that the constant pressure applied to the array during deployment minimized the array bow and kept the the array nearly straight between the Shark and the tail. Table 32 shows the latitude and longitude of the hydrophone locations along the HLA.

VLA thermistor data and ASIS buoy surface temperature data, as well as the mean salinity data from a nearby CTD cast, were used to calculate sound speed along the VLA to the surface. Due to absence of the actual salinity time series at the mooring site, the salinity was assumed to be a constant profile since its impact on the sound speed is much less then that of temperature variation. A mean sound speed calculated from below the channel receiving the signal to the bottom of the VLA was used to convert from travel time to distance along the LBL path.

The method used to calculate VLA array motion was a standard least squares inverse. To reduce some of the oceanograhpic effects of the LBL calculations, the estimated position of channel 13 was used as a VLA reference origin, since it is located 1.75 meters above the shark and should not have moved. All final VLA LBL positions were referenced to it.

Figure 6.9 shows the position of channel #0 on the VLA in relation to the Shark. The mean of the displacements for the VLA LBL and the mean depth variation of the detided pressure sensor on the VLA show an ~2.5 meter horizontal deviation from the Shark anchor location for the channel at the top of the VLA creating a ~3 degree mooring tilt. Larger variations in the tilt angle were seen during the time of the local storms. According to a spectrum of the displacements, the dominant frequency was 12.5 hours which corresponds to the M2 tide time scale.

Oceanography changes at the Shark added to the variability of the hydrophone localization on the VLA. The oceanographic effects are being investigated in more detail and will be available later in an addendum to this manuscript.

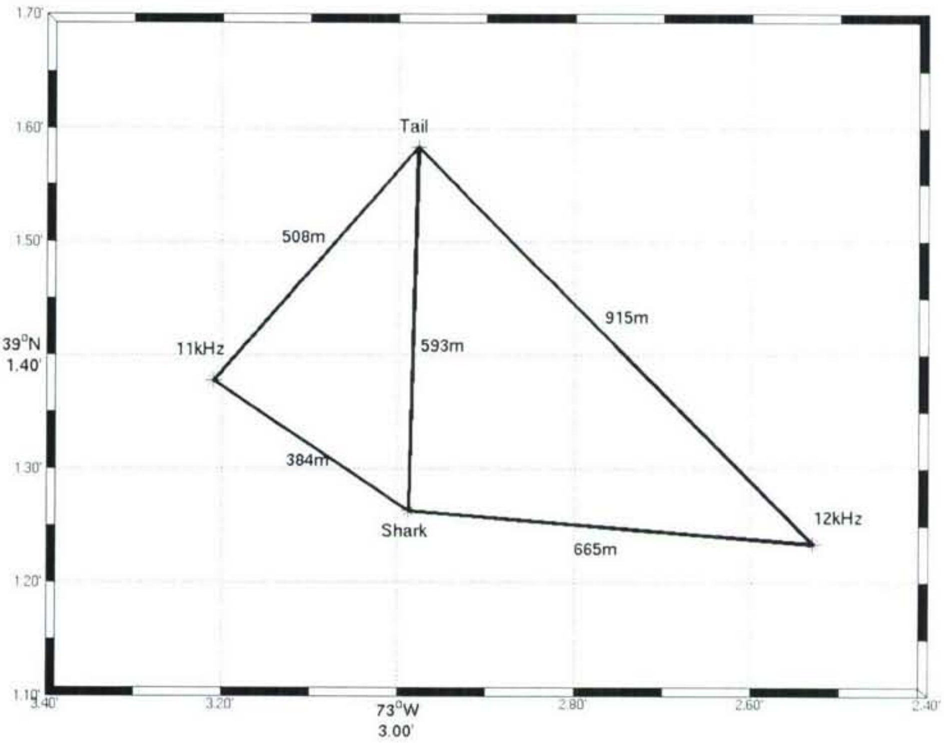

Figure 6.8 Shark LBL geometry looking down from surface. Distance (in meters) between interrogator in tail, transponders, and Shark is also noted.

Table 32: Locations of hydrophones on the Shark HLA.

Ch# on array	***Ch# stored in data file***	***Latitude (N) Longitiude (W)***	***Distance (m) from Shark***
16	32	39 01.5156 73 02.9804	468
17	8	39 01.5074 73 02.9807	453
18	33	39 01.4993 73 02.9809	438
19	9	39 01.4912 73 02.9812	423
20	34	39 01.4831 73 02.9815	408
21	10	39 01.4750 73 02.9817	393
22	35	39 01.4669 73 02.9820	378
23	11	39 01.4588 73 02.9823	363
24	36	39 01.4507 73 02.9825	348
25	12	39 01.4426 73 02.9828	333
26	37	39 01.4345 73 02.9831	318
27	13	39 01.4264 73 02.9833	303
28	38	39 01.4183 73 02.9836	288
29	14	39 01.4102 73 02.9839	273
30	39	39 01.4021 73 02.9841	258
31	15	39 01.3940 73 02.9844	243
32	40	39 01.3859 73 02.9847	228
33	16	39 01.3778 73 02.9849	213
34	41	39 01.3697 73 02.9852	198
35	17	39 01.3616 73 02.9855	183
36	42	39 01.3535 73 02.9857	168
37	18	39 01.3454 73 02.9860	153
38	43	39 01.3373 73 02.9863	138
39	19	39 01.3292 73 02.9865	123
40	44	39 01.3211 73 02.9868	108
41	20	39 01.3129 73 02.9871	93
42	45	39 01.3048 73 02.9873	78
43	21	39 01.2967 73 02.9876	63
44	46	39 01.2886 73 02.9879	48
45	22	39 01.2805 73 02.9881	33
46	47	39 01.2724 73 02.9884	18
47	23	39 01.2643 73 02.9886	3

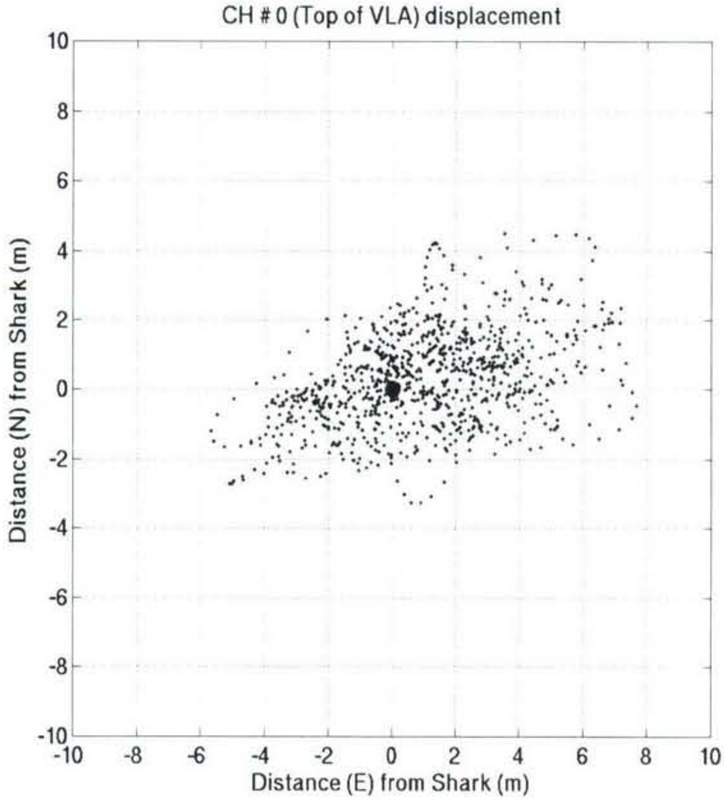

Figure 6.9 Vertical line array displacements for LBL phone #0 at the top of the array. Shark position is at 0,0.

7.0 Webb Hydrophone array

An 8 element, vertical hydrophone array designed at WRC was used on the R/V Sharp as a tethered instrument and on the R/V Oceanus as a deployed mooring (SW59). Since the data from the R/V Oceanus is being analyzed and archived at WHOI, the mooring configuration is listed here in Table 33. Figure 7.1 displays a typical spectrogram from the Webb array at phone #8 (1-8). A number of temperature sensors were attached to the mooring and are described in Table 34. Figure 7.2 displays a time series of the temperature data on the Webb array.

At first look, Webb array hydrophone #2 didn't work. There were a total of 21 data files from SW06. Each file size is 3683840016 bytes. The array sampled continuously at 8000Hz, except for the last 20 secs of each file where it stopped sampling to write data to disk. All data files began exactly on the 8 hour mark. The clock was synced to GPS time before deployment to only about 0.5 seconds accuracy, and unfortunately, the clock was not checked at recovery to get drift.

Table 33: SW59 - Webb hydrophone array.

Webb Hydrophone Array	
Mooring number	SW59
deployed location	38 16.138N 072 51.721W
Depth	80m
Cutoff filters	50 Hz, 1000 Hz
Array start date	Aug 31 14:00 (day 243)
Sampling frequency	8000 Hz
Data file size	~3.6 GB
Number of hydrophones	8
Hydrophone #1 depth (@80m)	15.1
Hydrophone #2 depth (@80m)	23.1
Hydrophone #3 depth (@80m)	31.1
Hydrophone #4 depth (@80m)	39.1
Hydrophone #5 depth (@80m)	47.1
Hydrophone #6 depth (@80m)	55.1
Hydrophone #7 depth (@80m)	63.1
Hydrophone #8 depth (@80m)	71.1

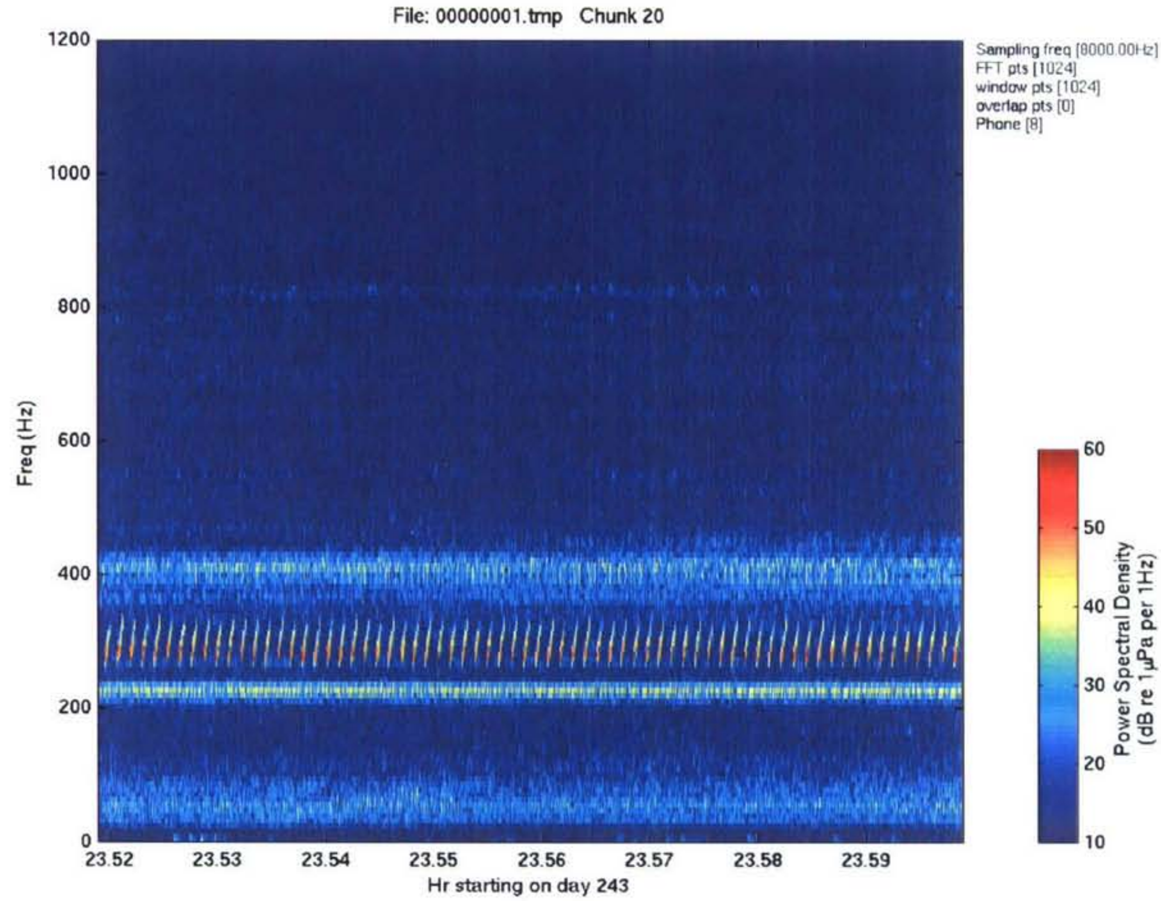

Figure 7.1 Typical spectrogram from the Webb hydrophone array.

Table 34: Environmental sensors on the Webb array.

Sensor	Sensor Number	Depth (m) at deployment depth (80m)	Sampling interval (secs)	Notes
SBE 37	4284	15.33 m	30	Above top phone
Tpod	2301	16.6 m	2	
Tpod	2299	24.6 m	2	
Tpod	2023	32.6 m	2	
Tpod	2304	40.6 m	2	
Tpod	2300	48.6 m	2	
Tpod	2297	56.6 m	2	
Tpod	2298	64.6 m	2	
Tpod	2049	72.6 m	2	

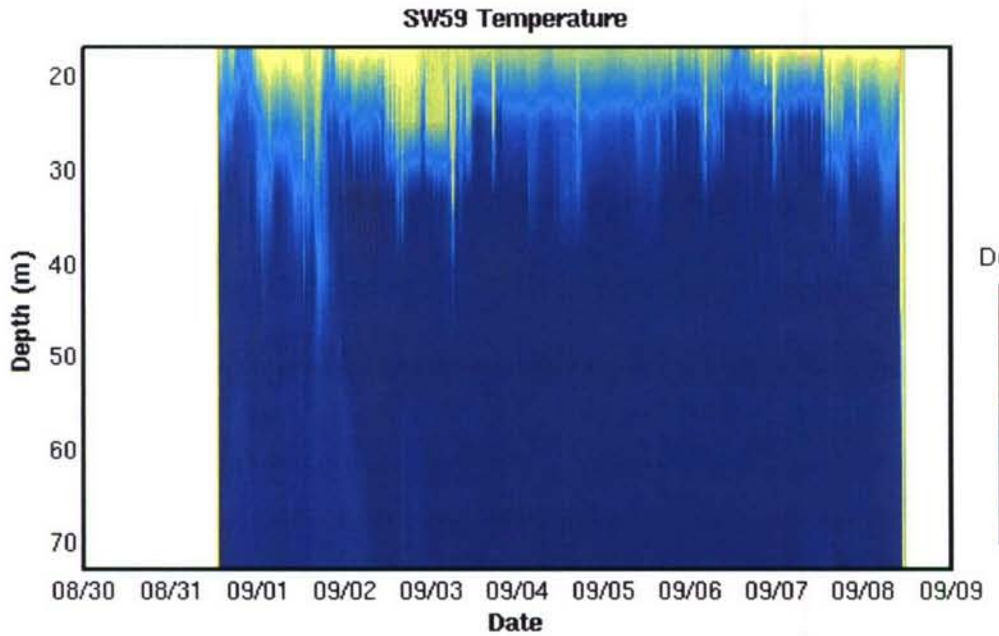

Figure 7.2 SW59 – Webb array temperature record.

8.0 Environment mooring data

WHOI deployed 34 moorings in a long- and across-shelf array (Figure 1.4) to sample the physical oceanography of the SW06 region. There were two types of moorings deployed – heavily instrumented Environmental Moorings (red dots in Figures 1.4 through 1.8) and less heavily instrumented Structure Moorings (yellow dots in Figures 1.4 to 1.8). There were 28 low cost, relatively sparsely instrumented (2-4 thermistors and a pressure sensor) Structure Moorings which were deployed as an array to resolve the structure of the internal waves as they passed through the site. Sixteen of the Structure moorings comprised the cluster at the intersection of the along-shelf and across-shelf paths (Figure 1.7) and the remainder were placed along each path – two beside each heavily instrumented Environmental mooring to form a small 3 mooring array within the larger array of Environmental Moorings. The moorings making up the cluster were logarithmically spaced between 0.5 km to 3 km to capture internal wave propagation at different scales. Six well-instrumented Environment Moorings were strategically placed to obtain complete, high resolution water-column sampling of the oceanography (Figure 1.4). The environment moorings contained multiple temperature, pressure and conductivity (salinity) sensors, and current profilers (ADCP). The 34 WHOI structure and environmental moorings with sensor type, serial number and depth (adjusted to pressure sensor) are given in Tables 35-40 and typical mooring diagrams shown in Appendix, section 15.2.

Each structure and environment mooring had a temperature sensor attached to the hi-flyer at about 1 m below the surface. Unfortunately, due to storms and/or fishing activity, only a few of these survived. The few that did survive seemed to be on the moorings that were furthest from the shelf break (i.e. in shallower water). Each structure mooring had a minimum of 2 Starmon mini temperature sensors and 1 Sea-Bird SBE39 attached just below the subsurface float (about 15 m) to measure temperature and pressure (to determine sensor depth and mooring motion). Some of structure moorings placed in deeper water had additional Starmon mini temperature sensors attached to them and one (mooring SW12) had a 1,200 kHz Waves ADCP in a flotation package above the standard subsurface float. The temperature sensors were attached to the moorings to sample the same water column depths of nominally 14, 25, 40, and sometimes 65 meters. All sensors were calibrated prior to the experiment.

The Environment Moorings contained significantly more sensors than the structure moorings and so there were only six of them. Each one had multiple temperature sensors for sampling the entire water column (Figure 8.1), pressure sensors at the top and bottom, conductivity (salinity) sensors coupled with many temperature sensors, and a 300 kHz ADCP. The ADCP was always located as near the bottom as possible, looking upwards. Deep mooring SW42 which also contained a second ADCP mid-way in the water column. Table 41 lists the ADCP profilers that were supplied by WHOI. Table 42 lists the model results obtained from the Geomagnetic Information and Forecast Service (http://www.geomag.bgs.ac.uk/gifs/on_line_gifs.html) to be used for ADCP orientation correction for magnetic variation (deviation).

The Environmental Moorings had Sea-Bird SBE37 Microcats to measure temperature, conductivity (salinity) and pressure. All the sensors on SW30 were Microcats which included an internal pump to reduce salinity errors by improving flushing of the conductivity cells. Where temperature only was measured on the Environmental Moorings, Sea-Bird SBE39 temperature sensors were used. To measure any water intrusions at the bottom, the across-shelf moorings had a Starmon mini temperature sensor attached to the acoustic release. Again the exact sensors used on the moorings is given in Appendix, Section 15.2

Table 35: WHOI Structure moorings – SW01-SW08

Site	*Deployment data / Sensorname*	*Location (Lat N Lon W) / Serial Number*	*Depth (m) Water/Inst*
SW01	30 jul 19:35	39 07.4425 73 17.2416	60
	SBE-39	311	14
	Mini-T	2030	25
	Mini-T	2031	35
SW02	30 jul 19:19	39 07.638 73 16.293	60
	SBE-39	313	13
	Mini-T	2032	24
	Mini-T	2033	35
SW03	29 jul 18:54	39 04.278 73 10.200	72.5
	Mini-T	256	1
	SBE-39	317	14
	Mini-T	2034	25
	Mini-T	2035	40
	Mini-T	2063	70
SW04	31 jul 11:18	39 01.9776 73 05.0551	83.5
	SBE-39	323	14
	Mini-T	2038	25
	Mini-T	2039	40
SW05	31 jul 11:40	39 02.213 73 04.8781	82.75
	SBE-39	324	15
	Mini-T	2040	26
	Mini-T	2041	41
SW06	31 jul 12:33	39 02.5721 73 04.6120	83
	SBE-39	326	15
	Mini-T	2042	26
	Mini-T	2043	41
SW07	31 jul 14:36	39 03.0240 73 04.272	84.25
	SBE-39	327	15
	Mini-T	2044	26
	Mini-T	2045	41
SW08	31 jul 15:46	39 01.7040 73 04.4520	82
	SBE-39	318	12
	Mini-T	2046	23
	Mini-T	2047	38

Table 36: WHOI Structure moorings – SW09-SW17

Site	*Deployment data / Sensorname*	*Location (Lat N Lon W) / Serial Number*	*Depth (m) Water/Inst*
SW09	31 jul 16:53	39 01.940 73 04.2810	84.5
	SBE-39	320	12
	Mini-T	2050	23
	Mini-T	2052	38
SW10	31 jul 17:35	39 02.286 73 04.023	87
	SBE-37P	4694	13
	Mini-T	2053	24
	Mini-T	2061	39
SW11	31 jul 18:00	39 02.757 73 03.671	85
	SBE-39	322	12
	Mini-T	2076	23
	Mini-T	2077	38
SW12	31 jul 22:58	39 01.734 73 03.828	87.25
	W-ADCP	6580	8
	SBE-37P	4848	14
	Mini-T	2066	25
	Mini-T	2087	40
SW13	31 jul 23:43	39 02.0869 73 03.5643	85.5
	SBE-39	243	15
	Mini-T	2089	26
	Mini-T	2036	41
SW14	01 aug 14:14	39 01.371 73 03.692	78
	SBE-39	3076	12
	Mini-T	2065	23
	Mini-T	2073	38
SW15	01 aug 15:03	39 01.596 73 03.528	80.5
	SBE-39	3077	12
	Mini-T	2068	23
	Mini-T	1991	38
SW16	01 aug 15:36	39 01.95 73 03.264	85
	SBE-39	3078	13
	Mini-T	1992	24
	Mini-T	1993	39
SW17	01 aug 16:26	39 02.423 73 02.912	85
	SBE-39	1939	14
	Mini-T	1994	25
	Mini-T	1996	40

Table 37: WHOI Structure moorings – SW18-SW25

Site	*Deployment data / Sensorname*	*Location (Lat N Lon W) / Serial Number*	*Depth (m) Water/Inst*
SW18	01 aug 13:13	39 03.231 73 02.771	82.25
	SBE-39	3119	15
	Mini-T	2002	26
	Mini-T	2002	41
SW19	29 jul 13:20	39 06.17 73 00.5275	79
	SBE-39	3120	15
	Mini-T	2003	26
	Mini-T	2004	41
SW20	29 jul 12:28	39 06.3674 72 59.5731	80.5
	SBE-39	3121	15
	Mini-T	2005	26
	Mini-T	2006	41
SW21	28 jul 19:27	39 13.184 72 55.315	78.5
	SBE-39	3122	15
	Mini-T	2007	26
	Mini-T	2008	41
SW22	28 jul 18:53	39 13.387 72 54.358	79.5
	SBE-39	3123	15
	Mini-T	2010	26
	Mini-T	2011	41
SW23	26 jul 16:16	38 58.513 72 57.368	87.75
	SBE-39	3125	15
	Mini-T	2012	26
	Mini-T	2013	41
	Mini-T	2063	85
SW24	26 jul 16:50	38 57.439 72 54.963	106.5
	SBE-39	3125	16
	Mini-T	2014	27
	Mini-T	2015	42
	Mini-T	2016	67
SW25	26 jul 14:21	38 57.1573 72 54.3898	110
	SBE-39	3126	15
	Mini-T	2017	26
	Mini-T	2018	41
	Mini-T	2019	66

Table 38: WHOI Structure moorings – SW26-SW28

Site	*Deployment data / Sensorname*	*Location (Lat N Lon W) / Serial Number*	*Depth (m) Water/Inst*
SW26	26 jul 22:41	38 56.6108 72 53.1865	113.75
	SBE-39	3127	14
	Mini-T	2020	25
	Mini-T	2021	40
	Mini-T	2022	65
SW27	27 jul 15:04	38 56.8566 72 52.2051	122.5
	SBE-39	3128	15
	Mini-T	2024	26
	Mini-T	2025	41
	Mini-T	2026	66
SW28	27 jul 15:51	38 57.3049 72 51.8666	122.5
	SBE-39		14
	Mini-T		25
	Mini-T		40
	Mini-T		65

Table 39: WHOI Environment moorings – SW29-SW31

Site	*Deployment data / Sensorname*	*Location (Lat N Lon W) / Serial Number*	*Depth (m) Water/Inst*
SW29	30 jul 18:39	39 07.1749 73 16.6399	62.5
	Mini-T	275	1
	SBE37	406	16
	SBE39	3	24
	SBE37	1133	34
	SBE39	4	45
	ADCP	125	55
	SBE16	2098	55
	SBE26	306	55
	Mini-T	263	59
SW30	31 jul 21:25	39 01.501 73 04.007	86
	Mini-T	282	1
	SBE37	4850	14
	SBE37	4841	16
	SBE37	4842	20
	SBE37	4843	25
	SBE37	4844	32
	SBE37	4845	39
	SBE37	4846	47
	SBE37	4847	56
	SBE37	4849	65
	SBE37	4851	74
	ADCP	6958	74
	Mini-T	289	83
SW31	01 aug 11:58	39 02.549 73 03.214	83
	Mini-T	2069	1
	SBE37	1770	14
	SBE39	11	22
	SBE37	1137	32
	SBE39	12	43
	SBE37	1138	54
	SBE39	13	65
	SBE37	1771	75
	ADCP	6999	75

Table 40: WHOI Environment moorings – SW32-SW34

Site	*Deployment data / Sensorname*	*Location (Lat N Lon W) / Serial Number*	*Depth (m) Water/Inst*
SW32	29 jul 14:28	39 05.904 72 59.922	81
	Mini-T	2069	1
	SBE37	1770	15
	SBE39	11	23
	SBE37	1137	33
	SBE39	12	44
	SBE37	1138	55
	SBE39	13	66
	SBE37	1771	75
	ADCP	6999	75
SW33	28 jul 20:29	39 12.290 72 54.705	80
	Mini-T	2070	1
	SBE37	400	16
	SBE39	14	23
	SBE37	1139	33
	SBE39	16	44
	SBE37	1140	55
	SBE39	17	66
	SBE37	404	74
	ADCP	705	74
	Mini-T	2075	78
SW34	27 jul 14:21	38 56.37 72 52.566	124
	Mini-T	2071	1
	SBE37	396	13
	SBE39	18	19
	SBE37	716	29
	SBE39	19	40
	SBE37	458	51
	SBE39	20	62
	SBE37	1132	73
	SBE39	21	84
	SBE37	715	95
	SBE39	24	104
	SBE37	403	112
	Mini-T	2072	122

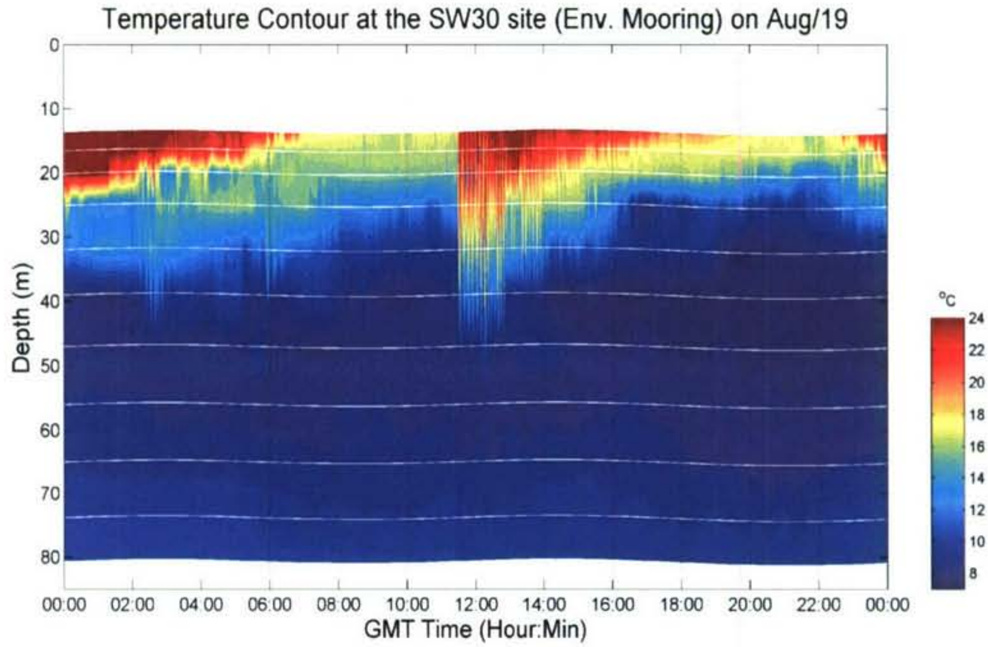

Figure 8.1 Temperature contour for August 19th from mooring SW30. The temperature sensor at the surface was lost. Notice the high frequency, nonlinear internal waves.

Table 41: WHOI moorings with an ADCP.

Mooring Number	ADCP Number	Depth (m) at deployment	Notes
SW29	125	55	
SW30	6958	75	
SW31	130	75	flooded
SW32	6999	75	
SW33	705	75	
SW42	2661	35	600 kHz
SW42	894	160	300 kHz

Table 42: Geomagnetic field model results for ADCP orientation.

Field Model Results for SW06		
Latitude	39 0.00 N	
Longitude	73 0.00 W	
Altitude	0.00 km	
Date	2006.50	
Component	**Field Value**	**Secular Variation**
Declination	-13.238 deg	1.8 arcmin/year

8.1 Environment mooring pressure and surface elevation tidal analysis

The six environmental moorings (SW29-SW34) had a Microcat pressure sensor near the top of the mooring (just below the subsurface float at about 14 meters depth) and near the bottom (just above the release at 5 meters above the bottom) to determine sensor depth and mooring motion. The bottom pressure sensor on SW29 was a wave and tide gauge. The pressure records at the bottom were analyzed for their tidal content, and a noise free prediction was subtracted from the top pressure sensor to study the mooring motion. Figure 8.2 shows an image of the data from both the top pressure sensors at mooring SW32 (blue), and the residual record (red) after the tidal prediction from the bottom pressure sensor was subtracted. A dip in the mooring would show up as a positive movement on the plot. There are no large movements in this plot, which is typical of all the moorings. The "noise" on the residual record is due to surface waves which reached 15 m depth. That they extend about equally on both sides of the mean depth, implies little mooring motion due to the surface waves, but does give an indication of storms – e.g. the smaller storm event around 16 August and the larger waves from Ernesto around 2 September.

As a "standard" tide for the SW06 site, the record from SW32 was selected as the most representative in the region, and the full tidal analysis of this record is given in Table 43 with the amplitude (dbars) and phase (Greenwich epoch) of the main tidal constituents (O1, K1, N2, M2, and S2). A summary of the analysis of all the pressure records shows that the M2 tide dominates, and that the phase is almost at a constant 352 degrees at all the moorings. The amplitudes are 0.44 dbars offshore, 0.46 dbars along the 80 meter isobath, and 0.48 dbars at the shallowest mooring.

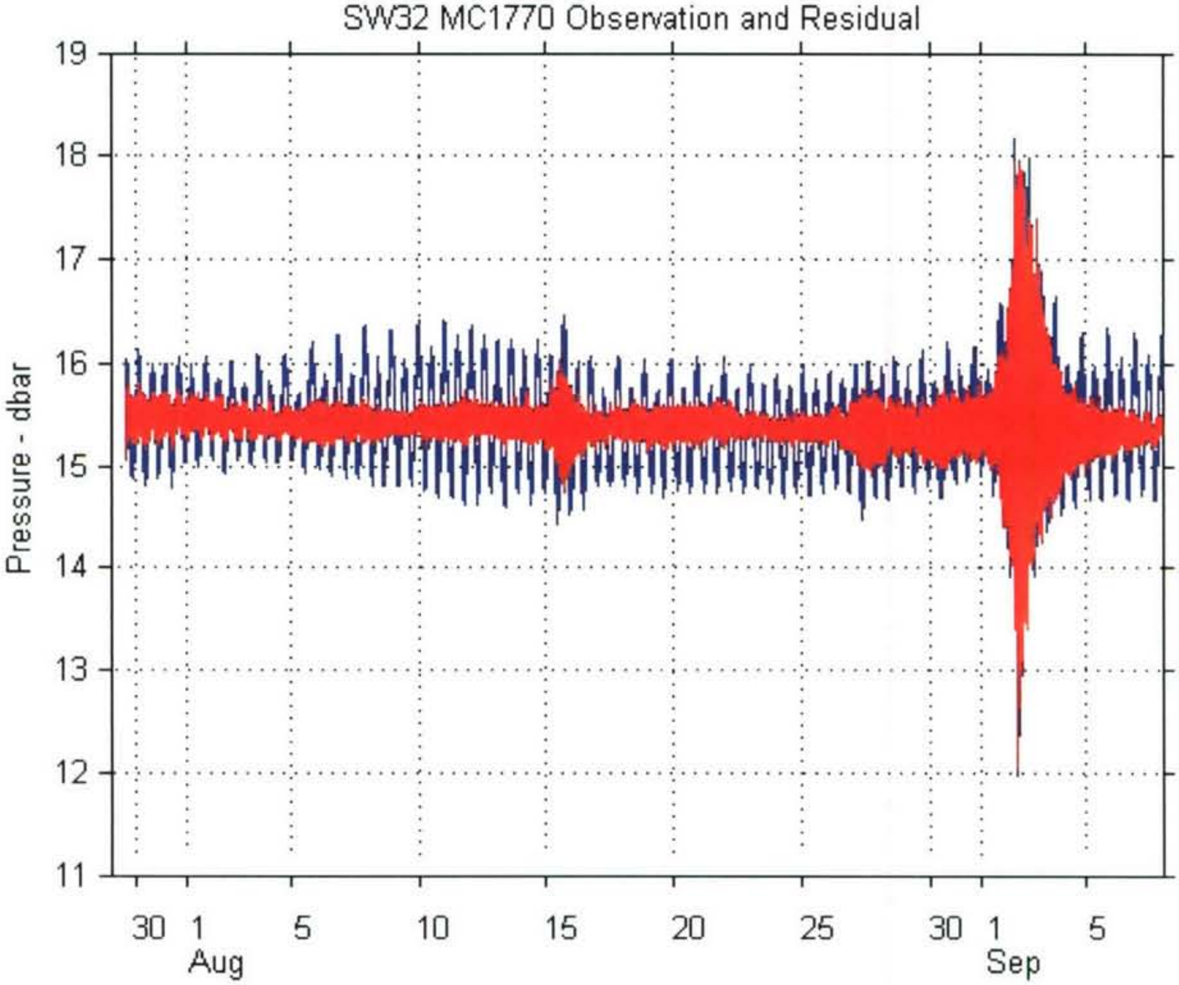

Figure 8.2: A plot of the observed pressure record from the upper pressure sensor (blue) and the residual (red) pressure record for the upper pressure sensor on mooring SW32.

Table 43: T_Tide analysis of SW32 bottom pressure - significant constituents for SNR >1.

date: 03-Apr-2007
nobs = 118041, ngood = 118041, record length = 40.99 days
start time: 29-Jul-2006 14:10:30
Greenwich phase computed with nodal corrections applied to amplitude and phase relative to series center time
percent variance predicted/variance observed = 98.4 %
tidal amplitude and phase with 95% CI estimates

tide	Freq (cycles/hr)	Amp (dbars)	amp_err	Pha (degrees)	pha_err	snr
*MM	0.0015122	0.0335	0.014	291.92	25.71	5.4
*MSF	0.0028219	0.0192	0.016	315.56	41.83	1.4
*2Q1	0.0357064	0.0043	0.003	209.02	34.92	2.5
*Q1	0.0372185	0.0162	0.003	175.72	9.78	35
*O1	0.0387307	0.0674	0.003	184.19	2.14	6.5e+002
*NO1	0.0402686	0.0061	0.002	183.60	17.10	9.2
*K1	0.0417807	0.0823	0.003	192.58	2.12	9.3e+002
*J1	0.0432929	0.0064	0.003	158.82	26.15	5.1
*OO1	0.0448308	0.0036	0.002	195.19	26.77	5.6
*EPS2	0.0761773	0.0081	0.006	330.55	49.69	1.9
*MU2	0.0776895	0.0226	0.006	315.12	15.93	16
*N2	0.0789992	0.1196	0.006	338.36	3.08	3.6e+002
*M2	0.0805114	0.4670	0.005	352.98	0.69	7.2e+003
*L2	0.0820236	0.0129	0.009	326.75	43.04	2
*S2	0.0833333	0.0980	0.006	32.14	3.29	2.9e+002
*M3	0.1207671	0.0023	0.001	33.72	41.10	2.6
*MN4	0.1595106	0.0007	0.001	217.02	45.23	1.2
*M4	0.1610228	0.0026	0.001	254.44	12.47	21
*MS4	0.1638447	0.0010	0.001	359.19	30.31	3.7
*2SK5	0.2084474	0.0010	0.001	20.94	34.11	3
*2MN6	0.2400221	0.0019	0.001	87.43	30.99	4.4
*M6	0.2415342	0.0029	0.001	129.19	17.63	9.1
*2MS6	0.2443561	0.0011	0.001	211.69	56.74	1.5

9.0 Bathymetry

High resolution bathymetry was initially provided by John Goff (University of Texas), using data from his participation in the STRATAFORM experiment which included the SW06 area. This bathymetry data is a compilation of (1)

STRATAFORM multibeam, (2) unpublished R/V Henlopen swath bathymetry (which covers the landward extension of the SW06 dip line) and (3) NGDC archive data over the entire region. The multibeam data take precedence over the NGDC data. Figures 9.1 and 9.2 show 2 different views of this high-resolution bathymetry data.

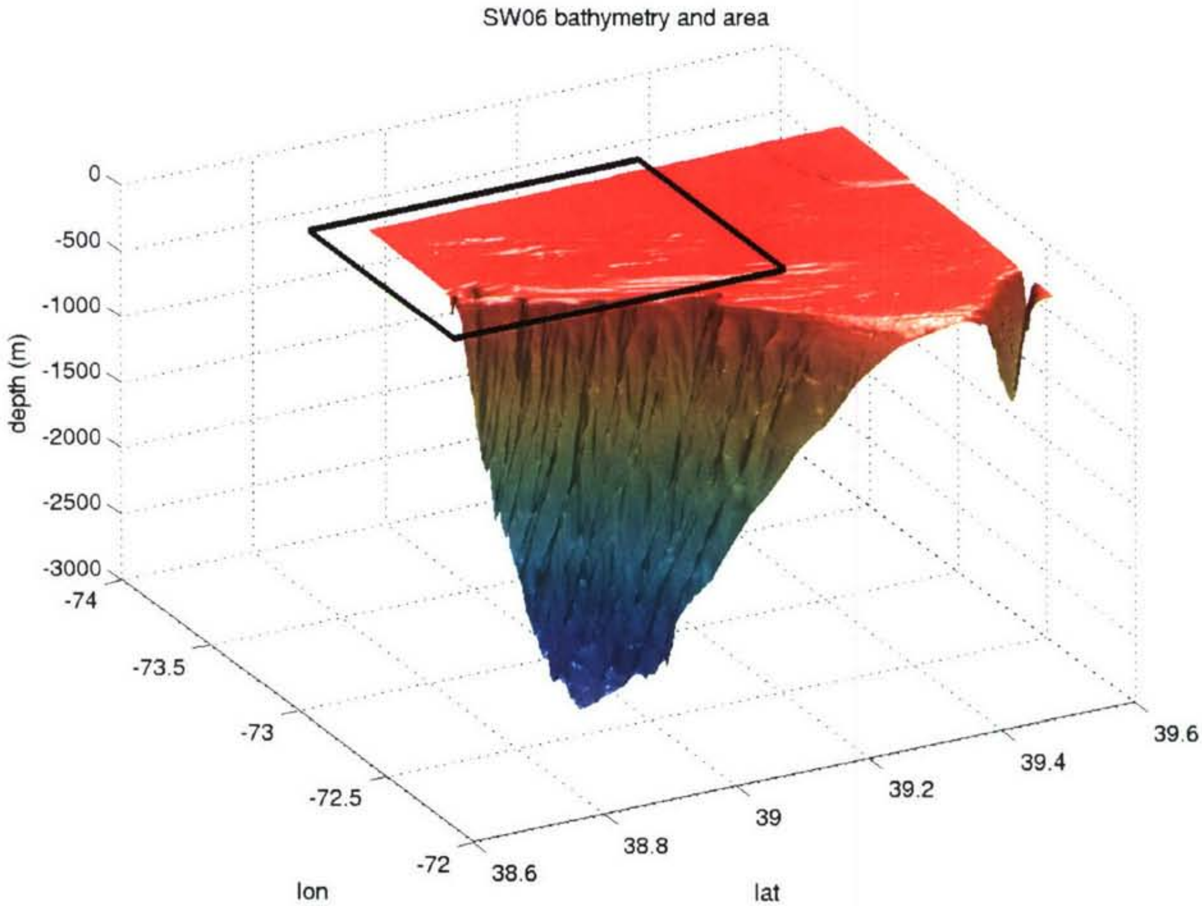

Figure 9.1 SW06 bathymetry image.

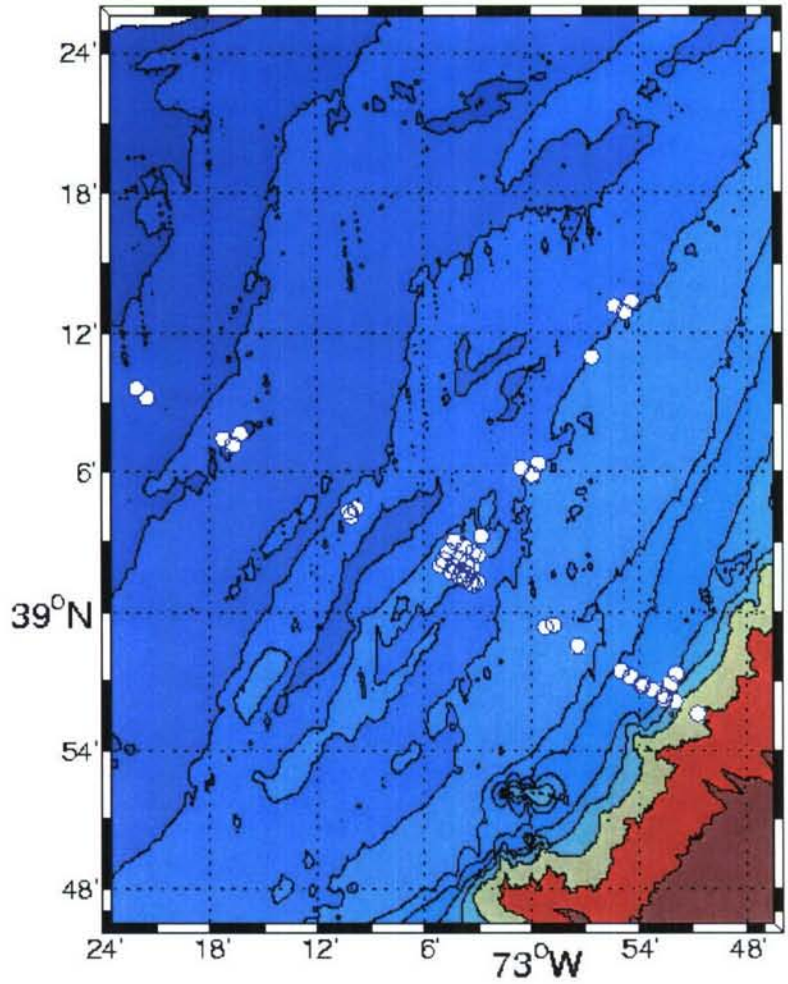

Figure 9.2 Top view of bathymetry at the SW06 site. Contours are at 40, 50, 60, 70, 80, 90, 100, 120, 150, 250, 500, and 1000 meters. Bathymetry data here were downloaded from a U.S. NOAA web site.

10.0 CTD/XBT data

10.1 CTD data

During the evening, when normal science operations may have ceased, some of the SW06 ships used that time to perform CTD casts to get spatial temperature and salinity measurements outside of the instrumented SW06 site area. The ships that performed those casts and the detailed locations of those casts are presented here in the following tables. Figure 10.1 displays a chart of the locations of all the CTD casts performed during the SW06 experiment.

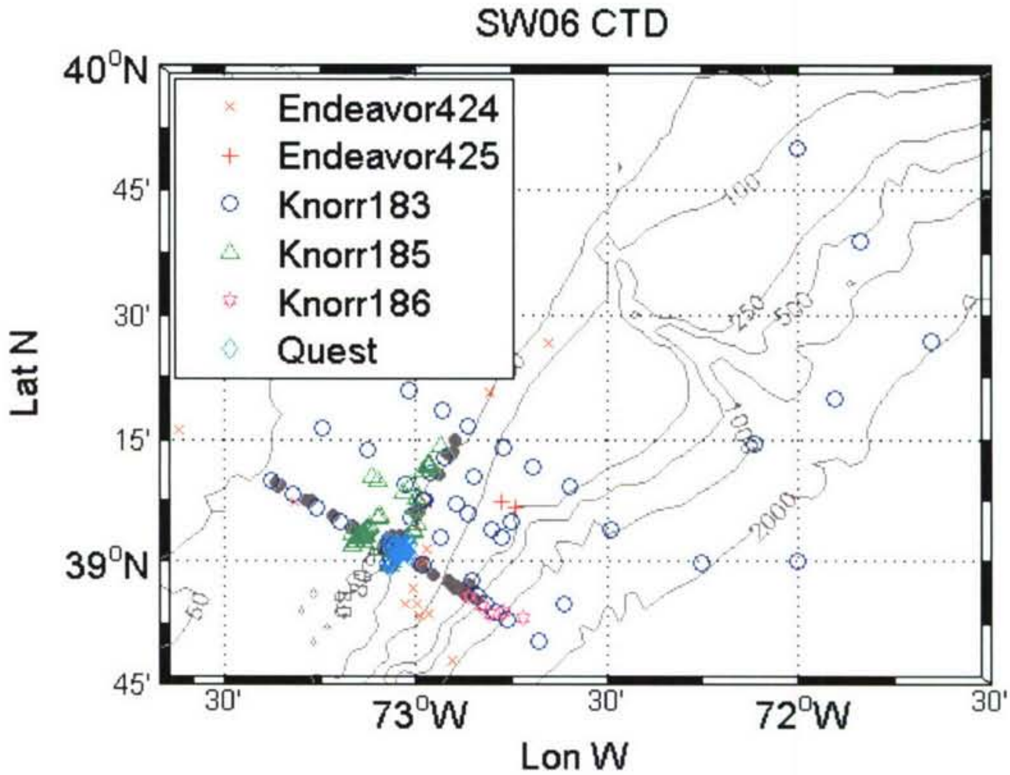

Figure 10.1 All CTD Stations performed during SW06.

============= KN183 CTD Casts =====================

ID	Date	UTC Time	Longitude(W) dd mm ss.s	Latitude(N) dd mm ss.s	Max_depth(m)
01	25-Jul-2006	23:01:31	73 04 00.6	39 01 31.2	81.1
02	26-Jul-2006	00:38:16	73 00 48.6	39 05 27.0	75.0
03	26-Jul-2006	02:02:56	72 55 25.8	39 12 46.2	74.5
04	26-Jul-2006	02:52:02	72 50 46.2	39 10 25.8	82.9
05	26-Jul-2006	03:38:51	72 53 29.4	39 06 56.4	82.4
06	26-Jul-2006	04:29:30	72 56 13.2	39 03 00.0	78.9
07	26-Jul-2006	05:30:52	72 58 52.2	38 59 31.2	81.4
08	27-Jul-2006	05:13:40	72 45 46.2	38 52 52.8	1082.6
09	27-Jul-2006	06:32:33	72 47 25.8	38 53 48.6	744.6
10	27-Jul-2006	07:35:13	72 48 55.2	38 54 50.4	641.8

11	27-Jul-2006	08:32:58	72 50 16.2	38 55 44.4	419.2
12	28-Jul-2006	02:24:24	72 35 50.4	39 09 09.0	242.4
13	28-Jul-2006	03:29:12	72 41 39.6	39 11 29.4	120.7
14	28-Jul-2006	04:30:36	72 46 09.6	39 14 01.8	94.9
15	28-Jul-2006	05:27:01	72 51 55.2	39 16 30.0	75.8
16	28-Jul-2006	06:13:22	72 55 50.4	39 18 33.0	63.9
17	28-Jul-2006	06:57:02	73 00 52.8	39 20 59.4	63.9
18	28-Jul-2006	07:39:48	73 05 10.8	39 23 12.6	51.0
19	29-Jul-2006	01:34:29	72 57 34.2	39 10 55.2	73.6
20	29-Jul-2006	03:57:21	73 22 41.4	39 09 48.6	49.2
21	29-Jul-2006	04:41:47	73 19 07.2	39 08 9.6	51.5
22	29-Jul-2006	05:26:05	73 15 24.6	39 06 33.0	65.3
23	29-Jul-2006	07:30:28	73 11 50.4	39 04 58.8	65.5
24	29-Jul-2006	08:19:46	73 08 19.2	39 03 27.6	61.1
25	29-Jul-2006	09:04:57	73 04 42.6	39 01 52.8	73.4
26	30-Jul-2006	00:22:19	72 58 43.8	39 07 37.8	75.6
27	30-Jul-2006	06:24:29	72 51 51.6	39 05 49.8	80.5
28	30-Jul-2006	07:15:04	72 48 01.8	39 03 52.2	110.3
29	30-Jul-2006	07:53:11	72 46 32.4	39 03 00.6	116.2
30	01-Aug-2006	02:09:11	72 45 06.6	39 04 51.6	125.1
31	01-Aug-2006	04:10:51	72 51 19.2	38 57 49.2	120.4
32	01-Aug-2006	23:51:48	72 58 32.4	39 07 28.2	74.5
35	02-Aug-2006	06:44:33	73 01 40.8	39 09 30.0	65.4
36	02-Aug-2006	07:37:10	73 07 24.0	39 13 40.2	65.4
37	02-Aug-2006	08:33:34	73 14 28.8	39 16 27.6	51.4
38	03-Aug-2006	03:04:36	72 40 37.8	38 50 13.8	746.2
39	03-Aug-2006	04:11:37	72 36 48.0	38 54 49.2	745.8
40	03-Aug-2006	05:46:10	72 29 18.6	39 03 49.8	745.7
41	03-Aug-2006	11:14:44	72 15 01.8	38 59 51.0	724.4
42	03-Aug-2006	13:18:27	72 00 07.8	39 00 01.2	742.6
43	03-Aug-2006	15:41:31	72 06 42.6	39 14 27.0	746.2
44	03-Aug-2006	17:15:21	71 54 03.6	39 19 56.4	743.1
45	03-Aug-2006	19:00:47	71 38 56.4	39 26 55.8	733.6
46	03-Aug-2006	20:58:11	71 50 06.6	39 39 00.6	647.1
47	03-Aug-2006	22:48:28	71 59 54.6	39 50 00.6	111.2

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======================== KN185 CTD Casts ====================

ID	Date	UTC Time	Longitude dd mm ss.s	Latitude dd mm ss.s	Max_depth(m)
01	24-Aug-2006	11:25:31	72 58 01.2	39 11 40.2	69.4
02	24-Aug-2006	20:06:15	73 07 55.8	39 03 10.2	62.6
03	25-Aug-2006	00:49:42	73 09 59.4	39 01 54.6	64.3
04	25-Aug-2006	05:34:41	73 09 39.0	39 02 22.8	64.9
05	25-Aug-2006	07:15:01	73 09 07.8	39 03 04.8	65.7
06	25-Aug-2006	08:15:34	73 08 33.6	39 03 30.0	63.9
07	25-Aug-2006	09:16:30	73 07 30.6	39 04 12.6	63.8
08	25-Aug-2006	10:29:20	73 05 55.8	39 05 16.8	65.8
09	25-Aug-2006	12:16:56	73 00 10.8	39 06 38.4	73.3
10	25-Aug-2006	16:39:08	73 02 16.2	39 01 22.8	74.0
11	26-Aug-2006	06:00:10	73 03 39.6	39 00 02.4	71.8
12	26-Aug-2006	16:39:10	73 02 41.4	39 01 07.8	73.3
13	26-Aug-2006	19:05:09	73 04 03.0	38 59 36.6	71.2
14	26-Aug-2006	19:49:01	73 05 23.4	39 01 31.2	82.3
15	27-Aug-2006	10:11:18	72 59 52.2	39 07 46.2	72.9
16	27-Aug-2006	14:44:30	73 06 44.4	39 10 21.0	68.0
17	27-Aug-2006	19:17:29	73 02 04.8	39 01 31.8	75.4
18	27-Aug-2006	19:54:56	73 02 04.8	39 01 31.8	73.8
19	27-Aug-2006	22:04:24	73 01 54.6	39 01 55.8	75.2
20	27-Aug-2006	22:52:22	73 01 12.6	39 02 52.2	76.2
21	27-Aug-2006	23:34:02	73 00 31.2	39 03 48.6	76.9
22	28-Aug-2006	00:14:05	72 59 49.8	39 04 44.4	78.5
23	28-Aug-2006	08:56:55	73 10 00.0	39 03 25.8	66.5
24	28-Aug-2006	12:39:25	72 56 05.4	39 14 17.4	69.3
25	28-Aug-2006	22:43:25	73 05 38.4	39 05 33.0	67.4
26	29-Aug-2006	04:50:32	73 01 58.8	39 08 25.2	65.2
27	29-Aug-2006	18:02:38	73 00 07.8	39 06 34.8	73.2
28	29-Aug-2006	19:04:15	73 05 53.4	39 09 58.2	69.9
29	29-Aug-2006	20:11:06	73 09 04.2	39 03 09.0	64.3
30	30-Aug-2006	00:19:26	73 01 54.6	39 01 55.8	74.8
31	30-Aug-2006	01:48:54	73 01 13.2	39 02 51.6	74.3
32	30-Aug-2006	02:29:42	73 00 31.2	39 03 48.0	75.5

33	30-Aug-2006	03:01:48	72 59 49.8	39 04 43.8	79.0
34	30-Aug-2006	15:31:13	72 58 04.2	39 11 54.0	68.2
35	31-Aug-2006	11:27:08	73 07 10.2	39 04 31.8	65.5
36	31-Aug-2006	14:29:43	73 02 04.2	39 01 31.2	73.0
37	31-Aug-2006	15:16:24	73 02 04.2	39 01 31.2	74.3
38	31-Aug-2006	19:53:23	73 01 56.4	39 01 57.0	74.7
39	31-Aug-2006	20:22:24	73 01 12.0	39 02 52.8	74.8
40	31-Aug-2006	20:46:13	73 00 31.8	39 03 49.8	76.6
41	31-Aug-2006	21:10:24	72 59 50.4	39 04 43.8	76.4
42	03-Sep-2006	12:41:02	73 08 14.4	39 02 33.0	64.1
43	03-Sep-2006	14:46:31	73 08 05.4	39 03 27.0	64.2
44	03-Sep-2006	22:09:09	73 08 01.2	39 03 36.6	65.7
45	04-Sep-2006	00:30:06	73 08 01.8	39 03 40.8	61.5
46	04-Sep-2006	03:20:03	73 09 28.8	39 02 36.6	64.8
47	04-Sep-2006	06:03:34	73 05 39.0	39 05 33.0	67.5
48	04-Sep-2006	13:13:33	73 07 46.8	39 04 03.0	65.4
49	04-Sep-2006	16:40:10	73 00 48.0	39 09 25.2	68.2
50	05-Sep-2006	11:52:28	73 08 45.0	39 02 58.8	65.6
51	05-Sep-2006	13:10:42	73 08 01.2	39 03 33.0	64.1
52	05-Sep-2006	14:13:42	73 08 01.2	39 03 35.4	63.8
53	05-Sep-2006	15:53:02	73 08 00.0	39 03 37.2	64.5
54	05-Sep-2006	17:09:36	73 08 03.6	39 03 27.6	64.1
55	06-Sep-2006	12:14:03	72 58 55.2	39 11 3.0	67.1
56	06-Sep-2006	15:14:07	72 57 52.8	39 12 4.2	68.7

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================== KN186 CTD Casts ===============

ID	Date	UTC Time	Longitude dd mm ss.s	Latitude dd mm ss.s	Max_depth(m)
01	13-Sep-2006	02:10:56	72 51 54.6	38 55 44.4	244.0
02	13-Sep-2006	02:56:37	72 49 43.2	38 54 28.8	489.5
03	13-Sep-2006	03:45:01	72 48 22.8	38 53 40.2	747.2
04	13-Sep-2006	04:46:33	72 46 18.0	38 53 46.2	980.9
05	13-Sep-2006	05:57:46	72 43 16.2	38 53 15.0	1231.9

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============== Endvr424 CTD Casts =====================

ID	Date	UTC Time	Longitude	Latitude	Max_depth(m)
01	04-Aug-2006	09:25:14	72 59 54.6	39 04 22.8	73.9
02	04-Aug-2006	23:28:10	72 58 23.4	39 07 07.8	76.0
03	05-Aug-2006	09:19:42	72 58 48.0	39 00 03.0	79.5
05	06-Aug-2006	08:56:44	72 58 15.0	39 01 29.4	78.0
06	06-Aug-2006	22:20:21	72 59 25.8	38 53 23.4	95.5
07	07-Aug-2006	17:39:48	72 54 16.8	38 47 46.8	152.6
08	08-Aug-2006	22:14:24	73 00 20.4	38 56 49.8	82.1
09	11-Aug-2006	11:55:23	72 58 03.0	38 53 38.4	99.0
10	11-Aug-2006	13:09:11	72 59 56.4	38 54 51.6	80.9
11	12-Aug-2006	18:47:34	73 18 55.8	39 07 19.2	57.9
12	12-Aug-2006	18:55:47	73 18 54.0	39 07 14.4	57.1
13	13-Aug-2006	18:19:41	73 01 22.8	39 00 48.6	77.0
14	16-Aug-2006	13:17:47	73 01 45.6	38 54 50.4	80.3
15	17-Aug-2006	19:19:56	73 37 00.6	39 16 04.2	45.6
16	17-Aug-2006	23:56:06	72 48 16.8	39 20 40.2	75.2
17	18-Aug-2006	20:54:56	72 39 01.2	39 26 33.6	89.9

============== Endvr425 CTD Casts ====================

ID	Date	UTC Time	Longitude	Latitude	Max_depth(m)
01	05-Sep-2006	12:43:16	72 46 25.2	39 07 16.8	120.5
02	05-Sep-2006	13:31:36	72 44 19.8	39 06 36.6	122.1

============== Quest CTD Spread Sheet ===================

ID	Date	UTC Time	Longitude	Latitude	Max_depth(m)
01	22-Jul-2006	12:17:40	73 04 11.4	39 00 04.2	66.5
02	22-Jul-2006	12:21:16	73 04 32.4	38 59 54.6	67.4
03	22-Jul-2006	12:47:00	73 04 02.4	38 59 30.0	65.2
04	22-Jul-2006	12:50:42	73 03 40.8	38 59 43.2	65.6
05	22-Jul-2006	12:54:24	73 03 24.0	38 59 58.8	65.6
06	22-Jul-2006	12:58:04	73 03 09.6	39 00 15.6	64.9
07	22-Jul-2006	13:04:25	73 02 45.6	39 00 44.4	65.5
08	22-Jul-2006	13:06:07	73 02 39.6	39 00 52.8	65.6
09	22-Jul-2006	13:09:15	73 02 29.4	39 01 07.8	71.7
10	22-Jul-2006	13:13:07	73 02 17.4	39 01 26.4	72.3
11	22-Jul-2006	13:16:57	73 02 04.2	39 01 44.4	72.5
12	22-Jul-2006	13:20:51	73 01 51.0	39 02 03.0	72.8
13	22-Jul-2006	13:24:45	73 01 37.8	39 02 21.6	72.2
14	22-Jul-2006	13:32:57	73 01 08.4	39 02 02.4	72.5
15	22-Jul-2006	14:06:30	73 01 03.0	39 00 55.8	73.8
16	22-Jul-2006	14:10:18	73 01 23.4	39 01 05.4	73.5
17	22-Jul-2006	14:14:08	73 01 45.0	39 01 15.0	72.8
18	22-Jul-2006	14:17:08	73 02 06.6	39 01 25.2	72.4
19	22-Jul-2006	14:21:50	73 02 29.4	39 01 34.2	72.5
20	22-Jul-2006	14:25:42	73 02 50.4	39 01 44.4	72.1
21	22-Jul-2006	14:29:36	73 03 12.6	39 01 54.6	73.3
22	22-Jul-2006	14:33:30	73 03 34.8	39 02 04.2	73.6
23	22-Jul-2006	14:37:26	73 03 57.6	39 02 14.4	74.1

24	22-Jul-2006	14:41:24	73 04 19.8	39 02 25.2	74.0
25	22-Jul-2006	16:28:44	73 03 05.4	39 01 18.0	70.9
26	22-Jul-2006	16:32:16	73 02 43.2	39 01 19.2	70.8
27	22-Jul-2006	16:35:52	73 02 20.4	39 01 19.2	72.2
28	22-Jul-2006	16:39:28	73 01 58.2	39 01 18.6	71.4
29	22-Jul-2006	16:44:14	73 01 29.4	39 01 18.6	72.7

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10.2 XBT

SW06 modelers depended on receiving some initial oceanographic information to initialize boundary conditions to put into their models, thus serving the SW06 community in near real-time. The XBT stations the modelers preferred were well outside of the SW06 area and so were typically performed during transit to or from the SW06 site. Figure 10.2 shows the locations of the XBT stations. The following tables list the XBT filenames and site information.

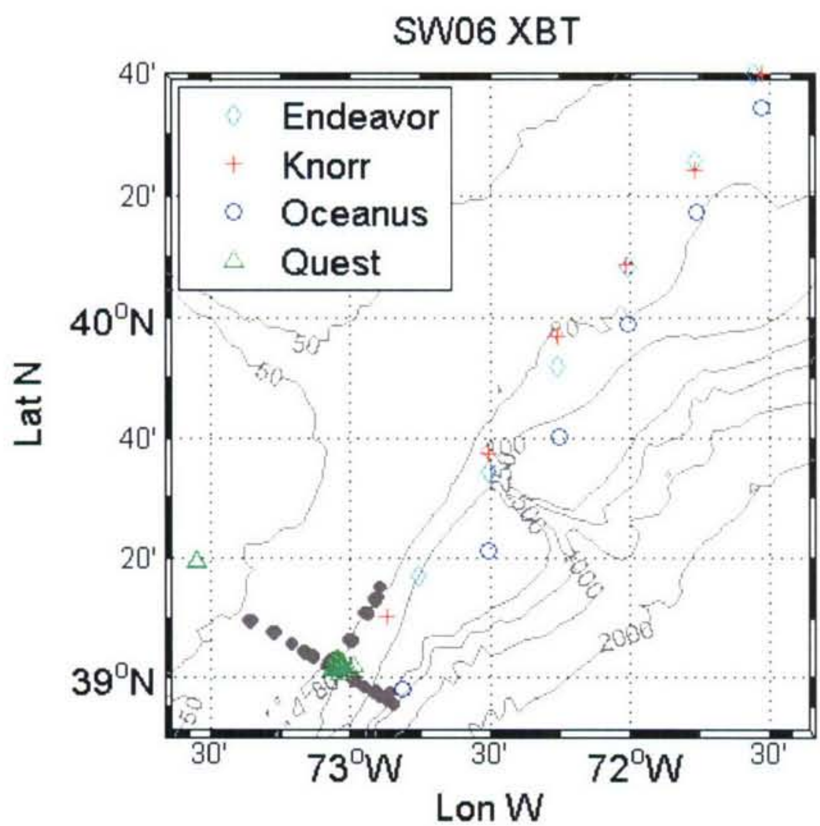

Figure 10.2 XBT stations performed during SW06.

================= Knorr XBT Locations =========================

File Name	Date	UTC Time	Longitude dd mm ss.s	Latitude dd mm ss.s	Max_depth(m)

probe_1	07-Aug-2006	22:08:08	71 30 09.1	40 41 25.9	424.5
probe_2	07-Aug-2006	23:54:55	71 45 44.0	40 24 14.1	760.4
probe_3	08-Aug-2006	01:32:45	72 00 45.1	40 08 33.7	760.4
probe_4	08-Aug-2006	02:54:28	72 15 22.1	39 56 47.2	292.5
probe_5	08-Aug-2006	04:40:23	72 30 22.1	39 37 23.1	307.6
probe_6	08-Aug-2006	07:17:26	72 52 15.7	39 10 10.6	309.4

Oceanus XBT Locations

File Name	Date	UTC Time	Longitude	Latitude	Max_depth(m)
T7_00115	31-Jul-2006	04:33:32	71 31 32.3	40 34 22.4	639.5
T7_00116	31-Jul-2006	06:33:28	71 45 28.4	40 17 14.9	383.6
T7_00117	31-Jul-2006	08:33:37	72 00 02.9	39 58 54.6	760.4
T7_00119	31-Jul-2006	10:32:26	72 15 05.1	39 40 05.7	760.4
T7_00120	31-Jul-2006	12:40:13	72 30 07.9	39 21 22.4	760.4
T7_00121	31-Jul-2006	15:01:09	72 48 39.8	38 58 06.3	541.2

Endeavor XBT Spread Sheet

File Name	Date	UTC Time	Longitude	Latitude	Max_depth(m)
T7_00012	03-Aug-2006	18:19:46	71 29 29.7	40 44 14.6	760.4
T7_00013	03-Aug-2006	20:08:07	71 45 41.7	40 25 37.9	760.4
T7_00014	03-Aug-2006	21:55:20	72 00 22.9	40 08 15.7	760.4
T7_00015	04-Aug-2006	00:26:46	72 15 14.1	39 51 55.2	760.4
T7_00016	04-Aug-2006	02:51:19	72 30 14.6	39 34 28.6	760.4
T7_00017	04-Aug-2006	05:15:35	72 45 20.8	39 17 06.8	760.4

Quest XBT Spread Sheet

File Name	Date	UTC Time	Longitude	Latitude	Max_depth(m)
S2_00002	19-Jul-2006	10:40:22	73 02 58.0	39 01 36.4	78.5
S2_00002_fix	20-Jul-2006	11:14:03	73 00 19.1	39 01 21.4	83.0
S2_00003	19-Jul-2006	11:15:17	73 02 16.2	39 01 53.7	108.4
S2_00006_fix	20-Jul-2006	23:30:04	73 33 02.6	39 19 37.1	49.6
S2_00007_fix	21-Jul-2006	11:26:33	73 00 15.7	39 01 22.3	83.0
S2_00009_fix	21-Jul-2006	23:23:40	73 02 58.6	39 03 03.4	83.0
S2_00012_fix	22-Jul-2006	11:29:09	72 59 14.2	39 02 02.2	83.0
S2_00014_fix	22-Jul-2006	23:31:04	73 01 51.7	39 02 30.1	79.6
S2_00017_fix	23-Jul-2006	11:33:53	73 03 46.3	39 01 25.0	79.6
S2_00025_fix	24-Jul-2006	23:25:38	73 02 45.4	39 01 41.2	79.6
S2_00028_fix	25-Jul-2006	11:29:03	73 02 09.8	39 00 40.3	78.5
T7_00001	19-Jul-2006	10:34:12	73 02 41.5	39 01 29.7	87.9
T7_00001_fix	20-Jul-2006	11:11:32	73 00 00.7	39 01 22.9	80.6
T7_00005_fix	20-Jul-2006	23:26:33	73 33 02.6	39 19 24.5	49.4
T7_00008_fix	21-Jul-2006	11:28:57	73 00 19.7	39 01 24.4	82.6
T7_00010_fix	21-Jul-2006	23:28:34	73 02 30.9	39 03 01.7	82.6
T7_00013_fix	22-Jul-2006	11:32:04	72 59 09.1	39 02 03.7	82.6
T7_00015_fix	22-Jul-2006	23:34:11	73 01 44.2	39 02 11.4	80.0

T7_00016_fix	23-Jul-2006	11:29:54	73 03 48.3	39 01 23.9	80.0
T7_00026_fix	24-Jul-2006	23:28:30	73 02 45.8	39 01 41.2	80.0
T7_00029_fix	25-Jul-2006	11:31:48	73 02 10.5	39 00 42.4	78.6

==

11.0 Shipboard data

All ships were equipped with sensors to monitor and log GPS ship position/speed/attitude, water depth, air and sea temperatures, and other ship-related information. Also logged were data from hull mounted ADCPs and imet data that includes wind speed and direction, air temperature, barometric pressure, relative humidity, short wave solar radiation, precipitation, sea surface temperature, sea surface conductivity, and a fluorometer. The principal investigator (PI) from each leg were given CDs containing this information. Most of all the shipboard data from all the ships was collected for distribution but any specific data can be obtained from contact with the PI from that leg (Table 2) .

11.2 Knorr

Table 44 lists the shipboard data available from the R/V Knorr. Data was collected from cruise numbers 183 (leg 1), 184 (leg 2), and 186 (leg 4).

Table 44: R/V Knorr shipboard data.

R/V Knorr Shipboard Data
75 kHz phased-array ADCP
150 kHz narrow band ADCP
Data log @ 1 minute
Date & time
Ship's heading (Gyro)
Speed log
GPS NMEA GGA, VTG data strings
IMET data {Wind, Bar, Hum, SW rad., Precip}
Sea surface temperature, conductivity, salinity
Flourometer
True wind speed (m/s) & direction
Bathymetry raw depth data
CTD/XBT data taken
Knudsen 12 kHz and 3.5 kHz chirp sonar bathymetry data

11.2.1 Seabeam sonar data

A SeaBeam 2100/12 system is installed on the R/V Knorr consisting of a number of underhull projectors and hydrophones (yielding a two-degree by two-degree beam pattern) which allows researchers access to high-resolution bathymetry and side-scan data while onboard. This system is optimal for deeper water (>100meters) so when normal SW06 operations ceased (during the night) and the ship was able to quickly steam off to deeper water, we surveyed the bottom along the shelfbreak close to the SW06 site. Figure 16.1 shows an image of one survey and shows numerous underwater canyons that lead to the site.

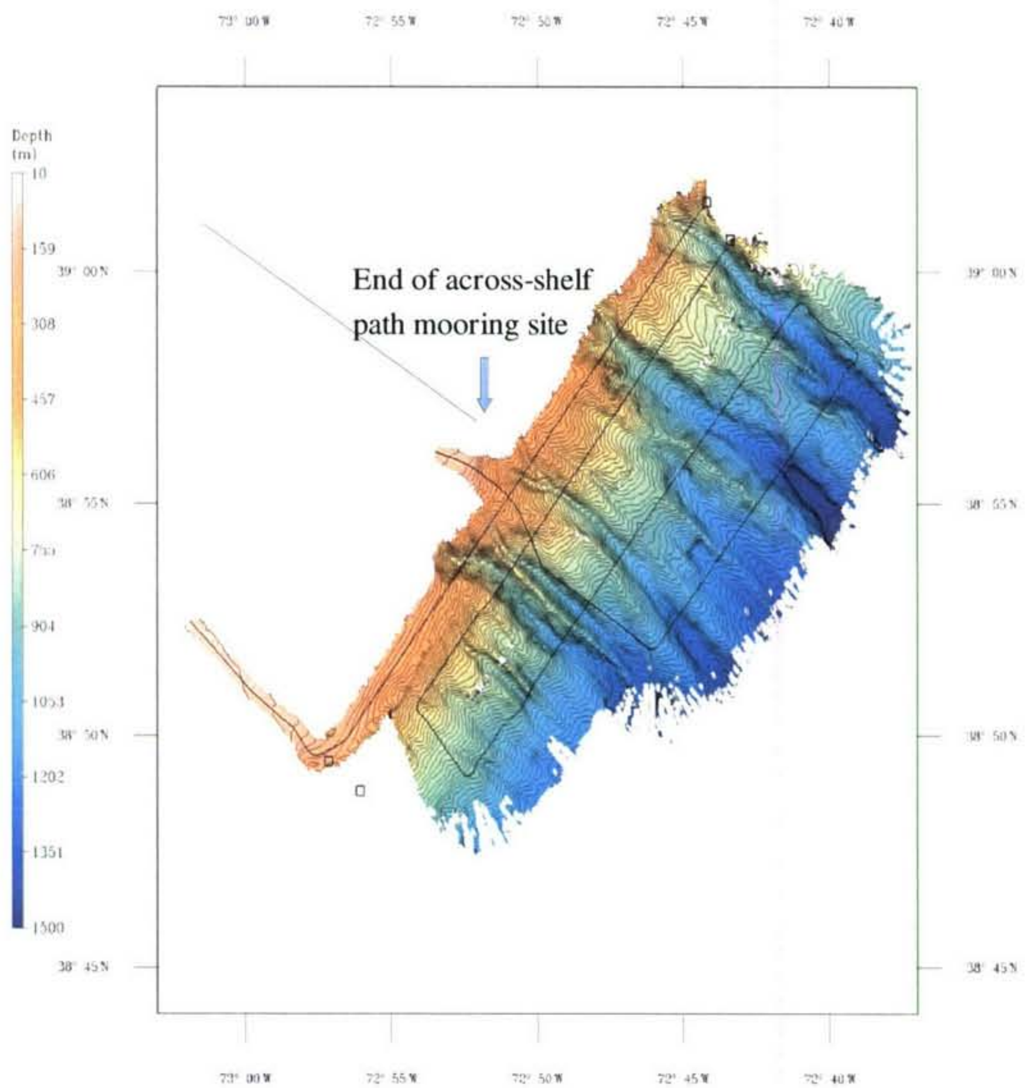

Figure 11.1 Seabeam bathymetry data.

11.3 Endeavor

Table 45 lists the shipboard data available from the R/V Endeavor. Data was collected from both legs for SW06, cruise numbers 424 (leg 1) and 425 (leg 2).

Table 45: R/V Endeavor shipboard data.

R/V Endeavor Shipboard Data
75 kHz ADCP
300 kHz ADCP
Data log @ 1 minute
Date & time
Ship's heading (Gyro)
Speed log
GPS NMEA data strings
IMET data {Wind, Bar, Hum, SW rad., Precip}
Sea surface temperature, conductivity, salinity
Flourometer
True wind speed (m/s) & direction
Bathymetry raw depth data
CTD/XBT data taken
Knudsen 12 kHz and 3.5 kHz chirp sonar bathymetry data

11.4 Oceanus

Table 46 lists the shipboard data available from the R/V Oceanus. Data was collected from both legs for SW06, cruise numbers 427 (leg 1) and 428 (leg 2).

Table 46: R/V Oceanus shipboard data.

R/V Oceanus Shipboard Data
75 kHz phased-array ADCP
150 kHz narrowband ADCP
Data log @ 1 minute
Date & time
Ship's heading (Gyro)
Speed log
GPS NMEA GGA, VTG data strings
IMET data {Wind, Bar, Hum, SW rad., Precip}
Sea surface temperature, conductivity, salinity
Flourometer
True wind speed (m/s) & direction
Bathymetry raw depth data
CTD/XBT data taken
Knudsen 12 kHz and 3.5 kHz chirp sonar bathymetry data

11.5 Sharp

Table 48 lists the shipboard data available from the University of Delaware's research vessel R/V Sharp, cruise number 060622CM..

Table 47: R/V Sharp shipboard data.

R/V Sharp Shipboard Data
75 kHz ADCP
Data log @ 1 minute
Date & time
Ship's heading (Gyro)
Speed log
GPS NMEA data strings
IMET data {Wind, Bar, Hum, SW rad., Precip}
Sea surface temperature, conductivity, salinity
Flourometer
True wind speed (m/s) & direction
Bathymetry raw depth data
CTD/XBT data taken
Knudsen 12 kHz and 3.5 kHz chirp sonar bathymetry data

12.0 ExView/communication application

The need for real-time field communication between multiple ships and shore led to the creation of a software application named ExView. This web-based tool enabled a coordinated collaboration between researchers at sea and on shore during this experiment and also archived the entire experiment for future viewing and information retrieval. It monitored and displayed the location of several ships, dozens of moorings, and other platforms in near real-time so all researchers at sea and on shore could visualize the progress of the experiment. It also provided, and archived, any pertinent information, ie, satellite images, weather reports, etc., that was useful to researchers during operations at sea.

A primarily wireless network comprised of satellite, shipboard and the global Internet was used to synchronize websites on five ships and multiple shore-based servers. All participants in the experiment could contribute and monitor platform locations/deployment, ship tracks, glider tracks, daily reports, weather information, CODAR imagery, satellite imagery, ocean model results, and other useful information. This tool collected and organized this information into a usable form and also provided a searchable, time-based archive of the entire experiment. The main display can be viewed in Figure 12.1.

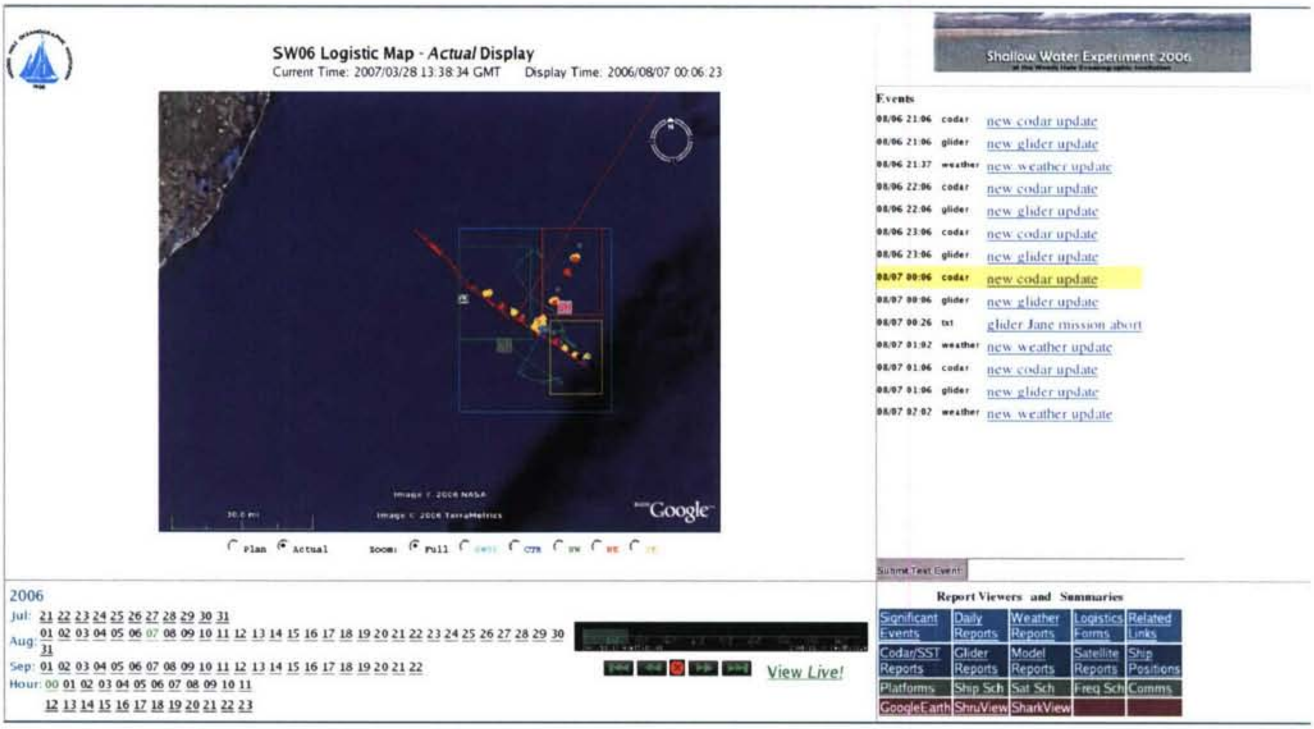

Figure 12.1 Main view of ExView application for August 7.

13.0 Additional data from SW06

Other useful data acquired during the SW06 experiment, that can complement the data/information presented in this report, is listed in this section. The Miami Sound Machine (MSM) transmitted frequencies outside of our normal signals to all our receivers. A Cessna (tm) Skymaster airplane flew out of a New Jersey airport daily for 2 weeks to observe internal wave surface expressions. Satellite coverage was acquired when any coverage was available. Available images are listed in Table 50, but images can only be downloaded with permission from Rosenstiel School of Marine and Atmospheric Science (RSMAS) at the University of Miami.

13.1 Miami Sound Machine (MSM) – SW44

A University of Miami multi-frequency, phase encoded signal, broadband source (Figure 13.1), known as the Miami Sound Machine (MSM), was deployed at the same site as the two NRL LFM sweep sources on the along-shelf path. It transmitted 5 frequencies (100Hz, 200Hz, 400Hz, 800Hz and 1600Hz) in succession according to one of two schedules described below. Due to a problem with the electronics the 400Hz signal level was extremely low.

The MSM was set up with 2 different schedules for SW06: one with continuous operation for 2 days until other researchers arrived and then the same schedule of 7.5 minutes on every half hour that the WHOI and NRL sources employ. The half-hourly schedule was created to leave some time available for other acoustician's to transmit without interference. For the first 2 days after it was deployed on July 28th , the MSM continuously transmitted rotating through each frequency starting with 100Hz. Each frequency was transmitted for 2 hours. When the second schedule started the MSM transmitted on the hour and half hour for only 90 seconds per frequency. The total transmission time was reduced to 7.5 minutes. More detailed signal information can be seen in Table 49.

Figure 13.1 Miami Sound Machine on deck.

Table 48: MSM specifications.

Miami Sound Machine Specifications			
Mooring number		SW44	
Deployment location		39 10.8708 N 72 57.0387W	
Date deployed		Jul 28 12:55 (Z)	
Date recovered		Sep 12 22:05 (Z)	
Continuous transmission started		Jul 28 18:00 (Z)	
Continuous transmission schedule		2 hrs per frequency, cycling	
Half-hourly transmission started		Jul 30 20:00 (Z)	
Transmission schedule		90 sec per frequency, starting at 100Hz	
Transmission stopped		Aug 25 05:30 (Z)	
Water Depth		79 m	
Frequency (Hz)	Bandwidth (Hz)	Octal Law	Sequence length
101.7253	25	103	63 digits
203.4505	50	203	127 digits
406.9010	100	435	255 digits
813.8021	200	1021	511 digits
1627.6042	400	2033	1023 digits
Tpod #2098		1 m	
Tpod #2099		75 m	

13.2 Skymaster

From Aug 8 to Aug 18, Bill Plant from the University of Washington flew aboard a Cessna (tm) Skymaster airplane (Figure 13.2) from shore out to the beginning of the SW06 across-shelf mooring array, along the across-shelf path, and then 40 miles beyond that. A typical flight path can be seen in Figure 13.3. He flew 16 missions in 10 days.

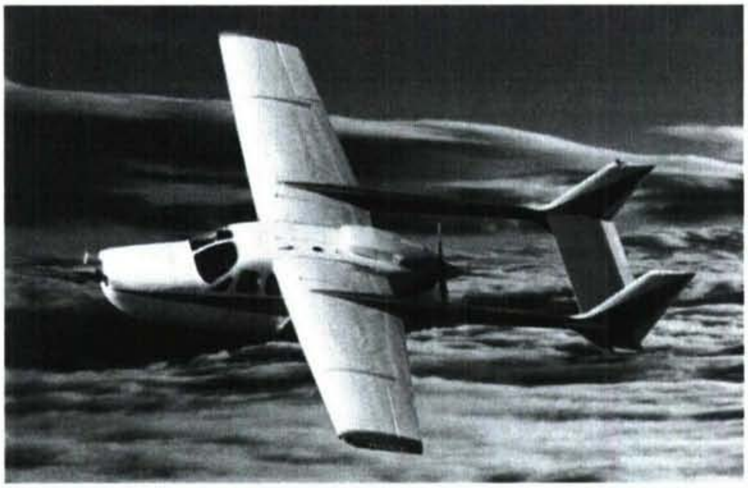

Figure 13.2 Photo of a Cessna Skymaster like the one used in SW06.

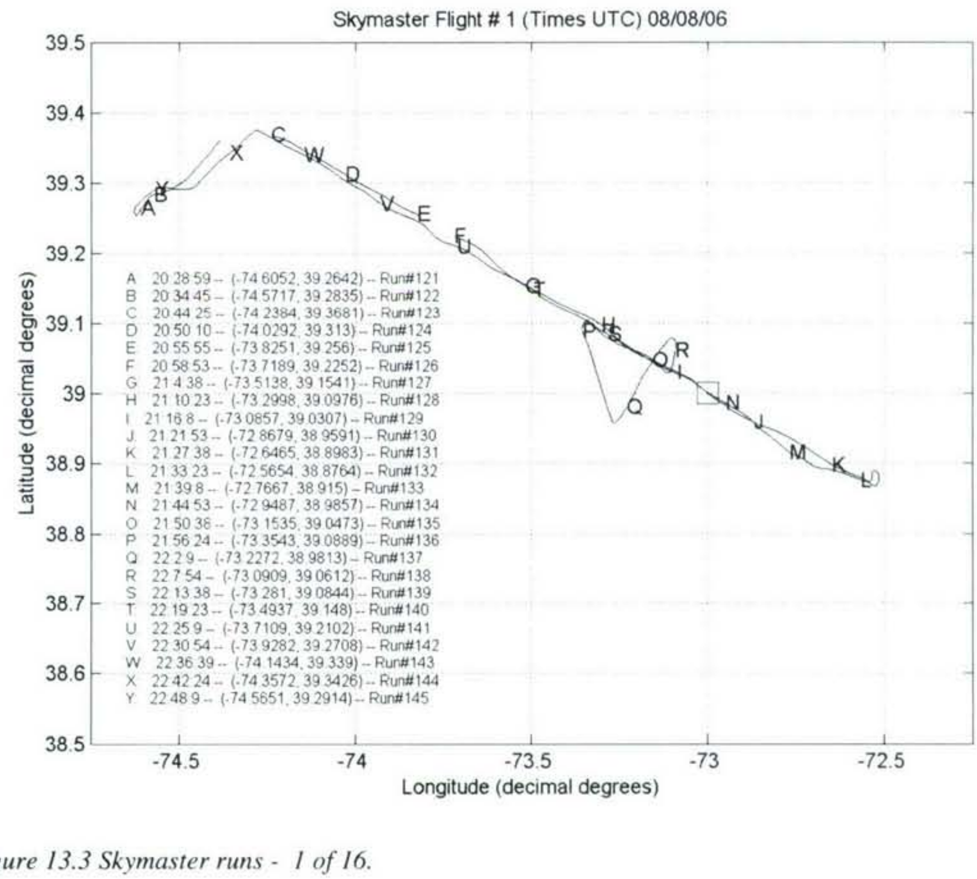

Figure 13.3 Skymaster runs - 1 of 16.

13.3 Satellite data

Satellite data is available through RSMAS at the University of Miami. Tables 50-53 show the acquisition times when satellite data was available over the SW06 site. Passes of RadarSat-1, ERS and ENVISAT are listed, as well as images from SPOT-2 and SPOT-4 satellites. Figure 13.4 shows a section of an ERS satellite image with colored dots depicting the locations of SW06 moorings.

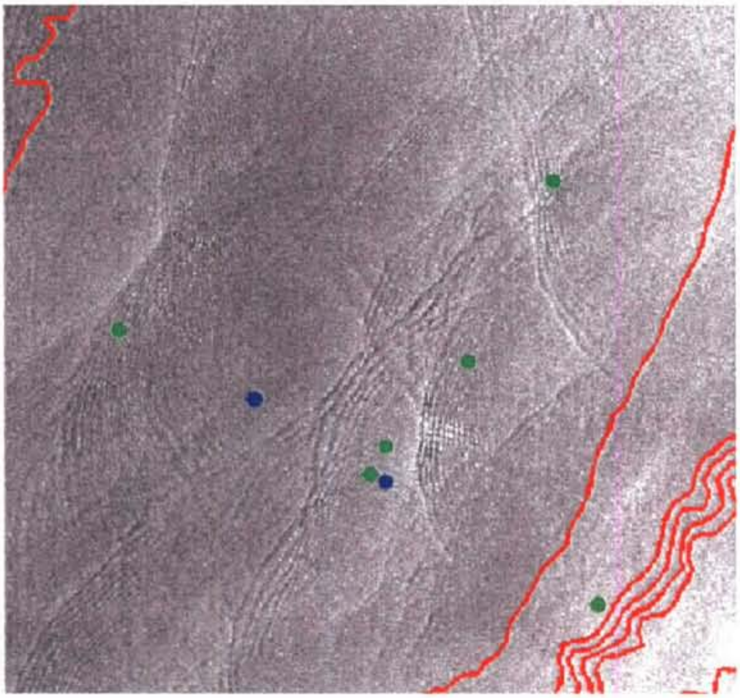

Figure 13.4 Satellite image showing internal wave activity at the SW06 site, courtesy of RSMAS and NASA.

Table 49: Satellite schedule for July.

date	ERS	ENVISAT	Radarsat	Spot-2	Spot-4
Jul 14	03:06	02:38			
Jul 19			22:33		
Jul 21				16:08	15:41
Jul 23	15:36	15:07			
Jul 25			22:58		16:04
Jul 26					15:45
Jul 27				15:53	
Jul 28				15:34	
Jul 29			22:41		
Jul 30	03:03	02:35	10:55		16:08
Jul 31					15:48

Table 50: Satellite schedule for beginning of August.

date	ERS	ENVISAT	Radarsat	Spot-2	Spot-4
Aug 01			22:54	15:57	
Aug 02	03:09	02:40		15:38	
Aug 05			22:37		15:52
Aug 06					
Aug 08	15:33	15:04	22:50		
Aug 09			11:03		
Aug 10					15:56
Aug 11				16:05	15:37
Aug 12			22:33	15:45	
Aug 13			10:47		
Aug 15			22:45		16:00
Aug 16			10:59		15:41

Table 51: Satellite schedule for end of August.

date	ERS	ENVISAT	Radarsat	Spot-2	Spot-4
Aug 17				15:49	
Aug 18	03:06	02:38	22:58		
Aug 20			10:43		16:04
Aug 21					15:45
Aug 22			22:41		
Aug 23			10:55	15:41	
Aug 25			22:54		16:08
Aug 26					15:49
Aug 27	15:36	15:07			
Aug 29			22:37		
Aug 30			10:51		
Aug 31					15:53

Table 52: Satellite schedule for September.

date	ERS	ENVISAT	Radarsat	Spot-2	Spot-4
Sep 01			22:50		
Sep 02			11:03		
Sep 03	03:03	02:35			
Sep 05			22:33		

13.4 OSU PO moorings

13.4.1 Bottom Landers

Four Oregon State University bottom landers with acoustic Doppler velocimeters (ADV), ADCPs and SeaBird microcats were deployed to measure wave direction and flow. Unfortunately, during the scheduled recovery none of the Bottom Landers released properly so would have to be recovered later. All four moorings were surveyed to get exact locations for later retrieval. Tables 54-57 show deployment information. Bottom Lander mooring SW39 had a lithium battery short which built up enough pressure inside the pressure case containing the batteries to cause an explosion on Aug 2 at 23:04:54 (Z).

Table 53: OSU Bottom Lander - SW37.

OSU Bottom Lander - SW37	
Deployment location	39 04.106 N 73 10.076 W
Surveyed position	39 04.1026 N 73 10.080 W
Date deployed	Jul 26 17:29 (Z)
Water Depth	71m
SBE-37 T/C	# 41

Table 54: OSU Bottom Lander - SW38.

OSU Bottom Lander - SW38	
Deployment location	39 01.230 N 73 03.402 W
Surveyed position	39 01.229 N 73 03.3973 W
Date deployed	Jul 29 16:17 (Z)
Water Depth	77m
SBE-37 T/C	# 42

Table 55: OSU Bottom Lander - SW39.

OSU Bottom Lander - SW39	
Deployment location	38 56.8045 N 72 53.8012 W
Surveyed position	N/A
Date deployed	Jul 26 17:29 (Z)
Water Depth	113m
SBE-37 T	# 43

Table 56: OSU Bottom Lander - SW40.

OSU Bottom Lander - SW40	
Deployment location	38 56.1978 N 72 52.5551 W
Surveyed position	38 56.2127 N 72 52.534 W
Date deployed	Jul 27 10:45 (Z)
Water Depth	127.5m
SBE-37 T/C	# 418

13.4.2 OSU Moorings

Three OSU well-instrument PO moorings were deployed in deeper water close to the shelf break. The following Tables 58-60 show their configurations.

Table 57: OSU PO mooring SW41.

OSU PO Mooring - SW41		
Deployment location	38 56.8970 N 72 53.7166 W	
Date deployed	Jul 27 21:59 (Z)	
Water Depth	114m	
Sensor	Number	Depth (m)
WHOI Tpod	0250	1 m
OSU SBE-39 T	263	11 m
OSU SBE-37 T/C	2526	16 m
OSU SBE-39 T	1782	22 m
OSU SBE-37 T/C	1816	30 m
OSU SBE-39 T	1843	39 m
OSU SBE-37 T/C	2527	48 m
OSU SBE-39 T	1844	59 m
OSU SBE-37 T/C	1818	70 m
OSU SBE-39 T	1845	81 m
OSU SBE-37 T/C	2528	93 m
OSU SBE-39 T	264	105 m

Table 58: OSU PO mooring SW42.

OSU PO Mooring - SW42		
Deployment location	38 56.0805 N 72 51.9543 W	
Date deployed	Jul 27 17:50 (Z)	
Water Depth	179.25m	
Sensor	Number	Depth (m)
OSU SBE-39 T	265	11 m
OSU SBE-37 T/C	2529	19 m
OSU SBE-39 T	1886	30 m
WHOI 600 kHz Workhorse ADCP	2661	
OSU SBE-37 T/C	2530	42 m
OSU SBE-39 T	1887	56 m
OSU SBE-37 T/C	2531	72 m
OSU SBE-39 T	1888	89 m
OSU SBE-37 T/C	419	108 m
OSU SBE-39 T	1889	128 m
OSU SBE-37 T/C	2523	149 m
WHOI 300 kHz Workhorse ADCP	894	
OSU SBE-39 T	267	170 m

Table 59: OSU PO mooring SW43.

OSU PO Mooring - SW43		
Deployment location	38 55.5931 N 72 50.6772 W	
Date deployed	Jul 27 17:50 (Z)	
Water Depth	466m	
Sensor	Number	Depth (m)
OSU SBE-39 T	664	11 m
OSU SBE-37 T/C	2533	20 m
OSU SBE-37 T/C	2372	30 m
OSU SBE-39 T	666	40 m
OSU SBE-37 T/C	2534	55 m
WHOI 500 kHz Sontek ADP		
OSU SBE-39 T	667	78 m
OSU SBE-37 T/C	420	101 m
OSU SBE-39 T	875	129 m
OSU SBE-37 T/C	421	158 m
OSU SBE-39 T	876	188 m
OSU SBE-37 T/C	2536	219 m
OSU SBE-39 T	168	251 m
OSU SBE-37 T/C	422	284 m
OSU SBE-39 T	175	318 m
OSU SBE-37 T/C	425	353 m
OSU SBE-39 T	231	388 m
OSU SBE-37 T/C	2537	424 m
WHOI 75 kHz Longranger ADCP	1429	
OSU SBE-39 T	235	461 m

13.5 University of Miami ASIS moorings

Two University of Miami ASIS buoys were deployed to measure atmospheric conditions to measure surface waves and to measure near surface temperature and currents. These will supplement the measurements taken in the deeper parts of the water column to get a good understanding of the complete oceanographic field. Tables 61 and list the mooring locations and depths.

Table 60: SW57 ASIS mooring locations.

ASIS Mooring #1 - SW57	
SW57 Deployment location	39 01.1483 N 73 03.2127 W
SW57 Date deployed	Jul 30 16:45 (Z)
SW57 Water Depth	77m

Table 61: SW58 ASIS mooring locations.

ASIS Mooring #2 - SW58	
SW58 Deployment location	39 04.434 N 73 09.846 W
SW58 Date deployed	Jul 31 11:00 (Z)
SW58 Water Depth	71m

14.0 Acknowledgments

First, we would like to thank those who made this part of the SW06 experiment possible, especially Ellen Livingston and Terry Paloszkiewicz, our acoustics and physical oceanography sponsors from the Office of Naval Research.

We would also like to thank the captains and crews of the ships, R/V Knorr, R/V Oceanus, R/V Endeavor, R/V Sharp, and the CFAV Quest, who supported our sea-going operations. Their skill and professionalism contributed immensely to the success of this experiment.

We would also like to thank all those in the WHOI buoy and rigging groups and all WHOI dock support personnel who spent long hours constructing most of these moorings, swiftly loading and unloading the boats, and going out of their way to make sure everyone had what they needed to successfully accomplish their missions.

15.0 References

[1] Newhall, Arthur, et. al., "Preliminary acoustics and oceanographic observations from the ASIAEX 2001 South China Sea experiment", WHOI Technical Report, WHOI-2001-12, September, 2001.

15.0 Appendices

15.1 CD

Some of these reports will have a CD included. Those that do not can get an online version at http://acoustics.whoi.edu/sw06_cd.html. The CD does not contain any data, but does include this document, SW06 transmission schedule, SW06 internal wave activity as logged by the R/V Sharp and the R/V Oceanus, the SW06 ship schedule and a sensor list spreadsheet which is also included in this appendix.

15.2 Mooring diagrams

The following mooring diagrams were made before going to sea and were used on-deck to help with configuring each mooring. A few representative diagrams are presented here.

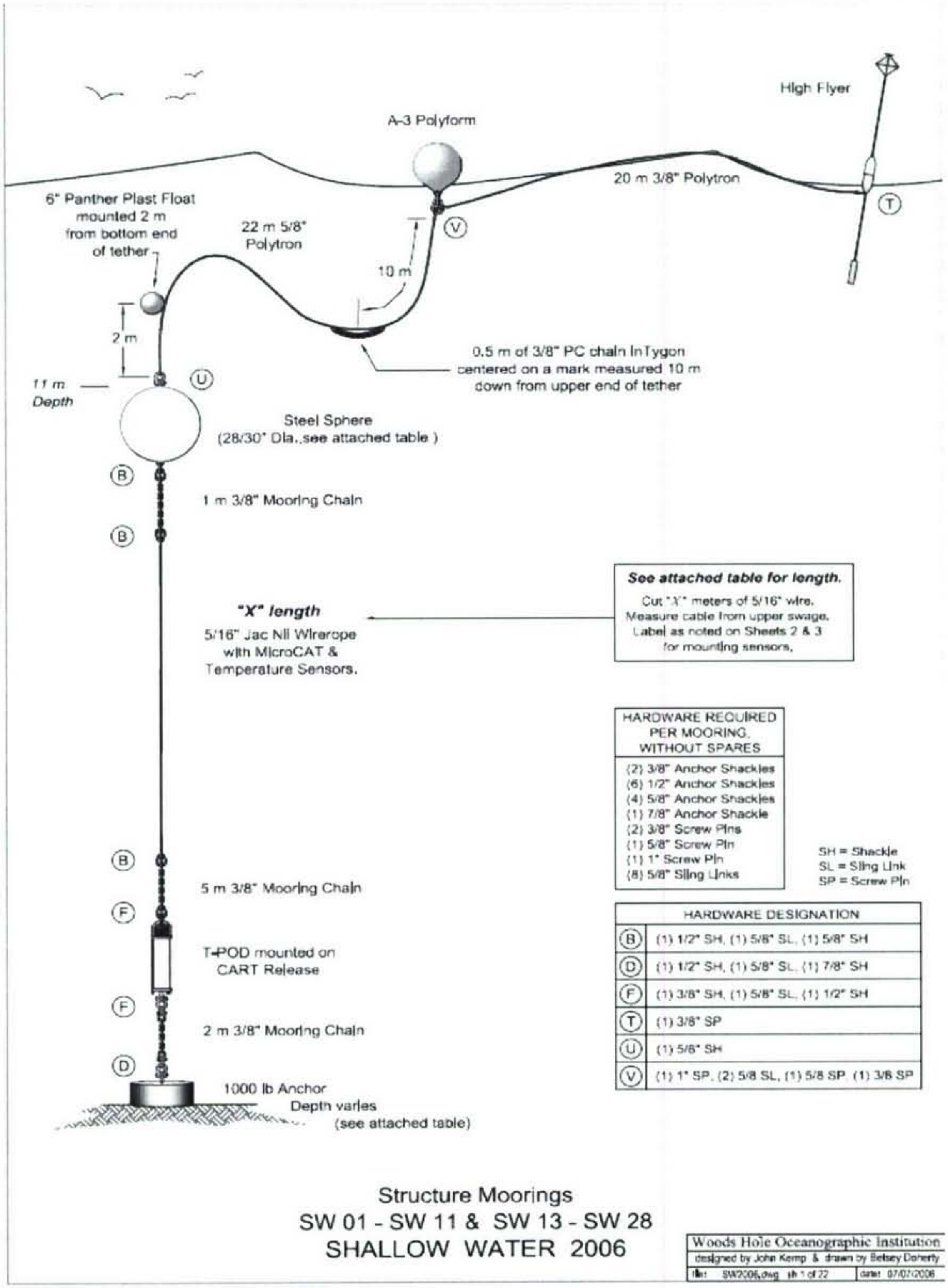

Figure 15.1 Structure mooring diagram.

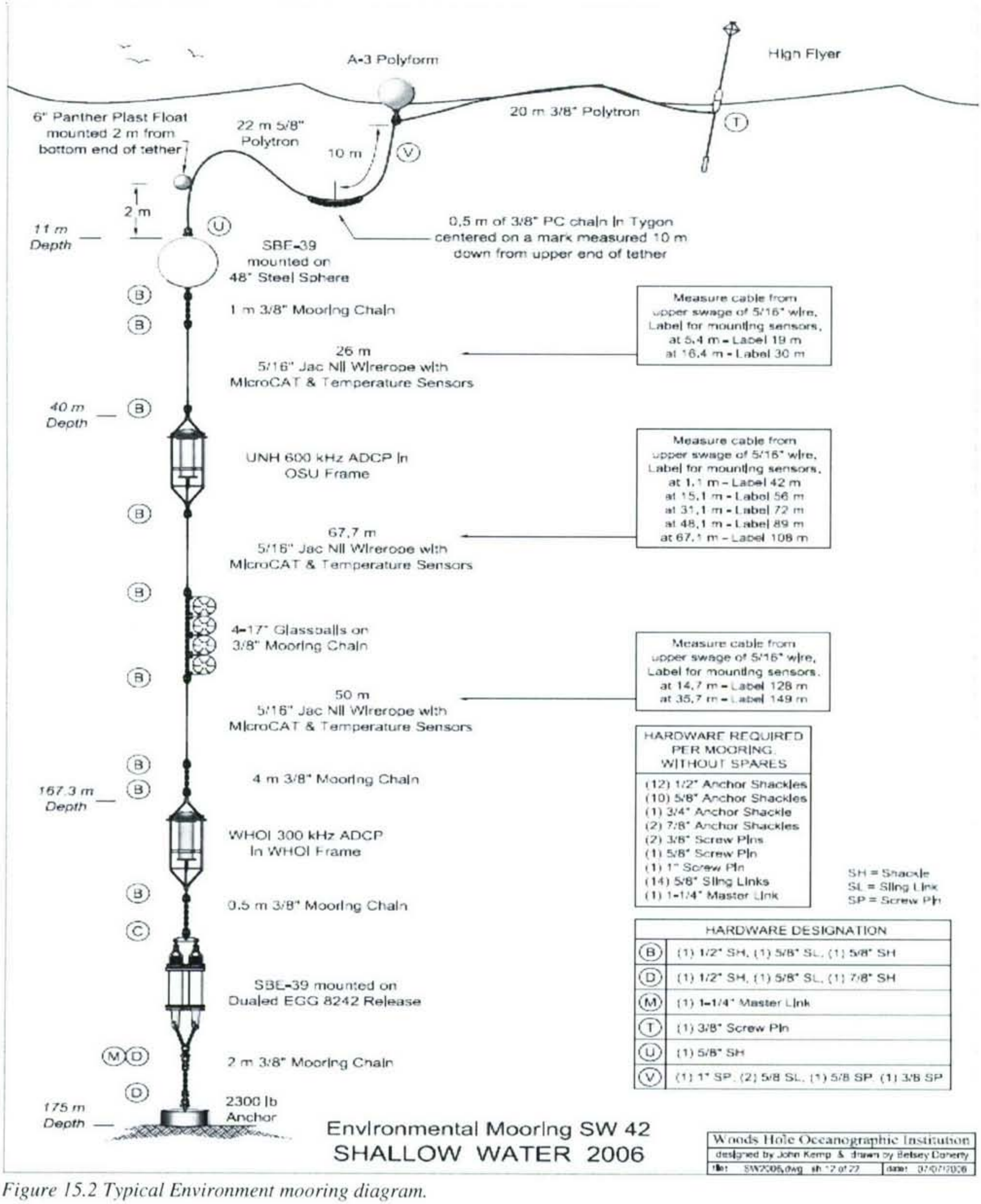

Figure 15.2 Typical Environment mooring diagram.

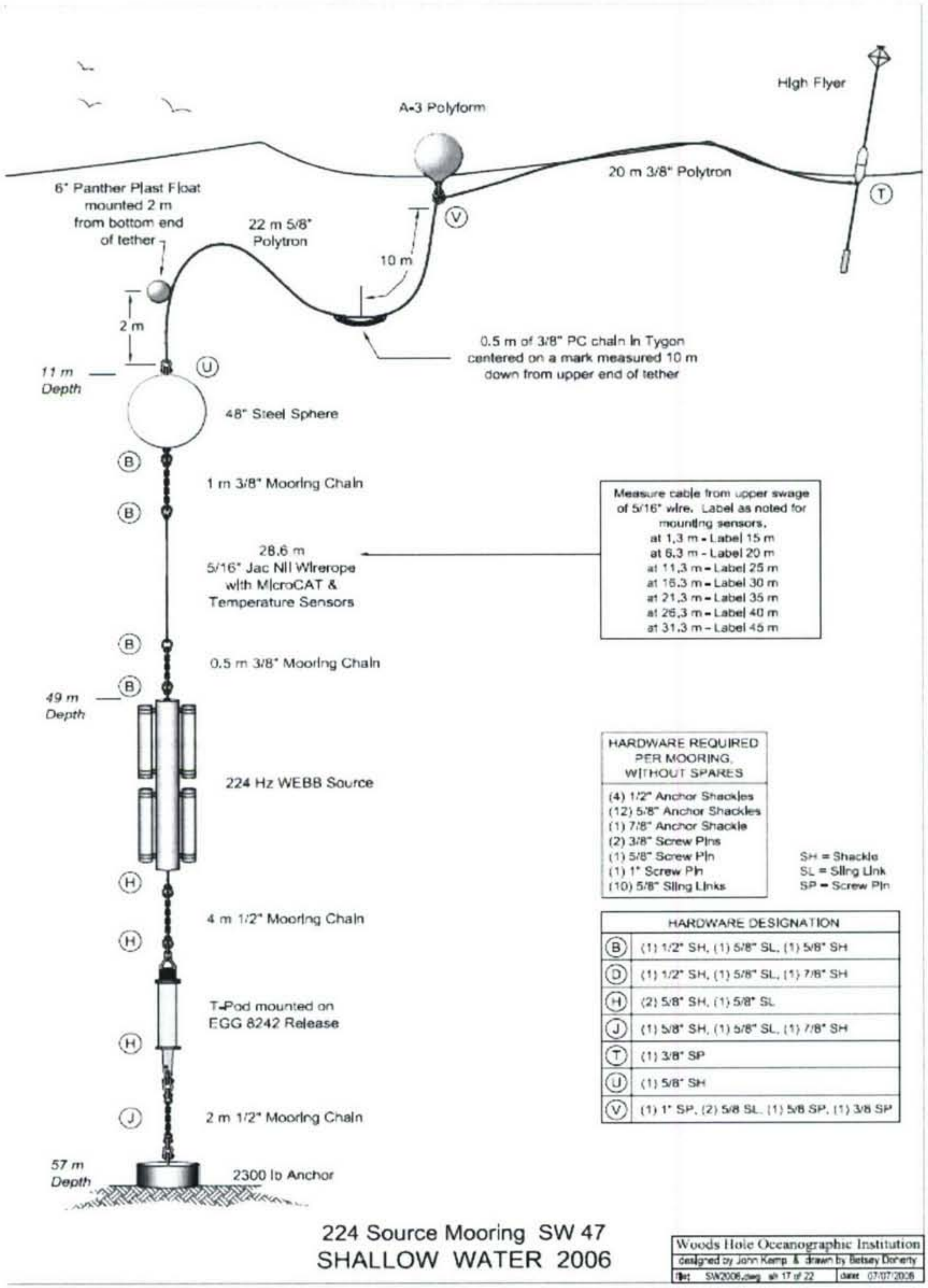

Figure 15.3 Typical source mooring diagram.

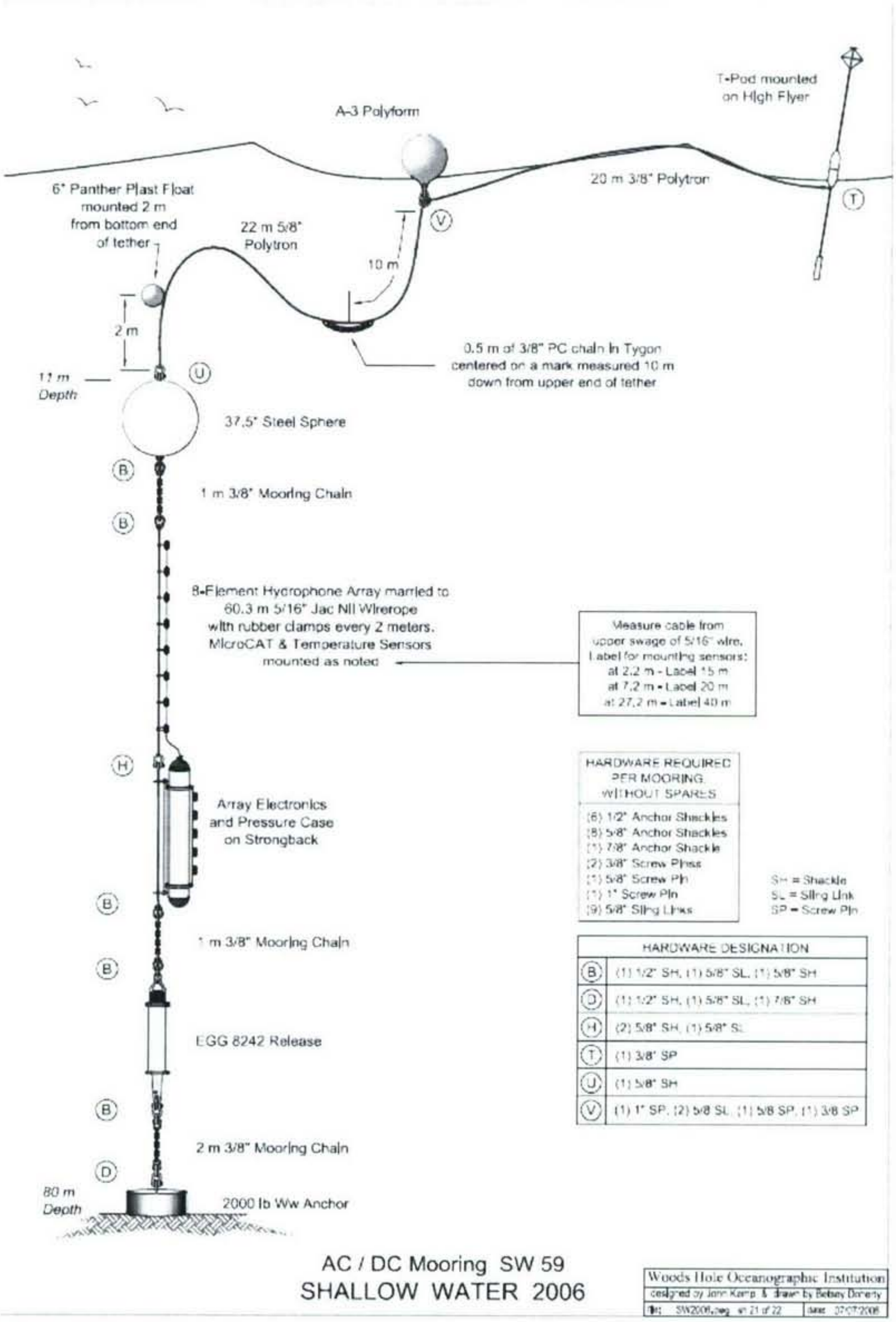

Figure 15.4Webb VLA diagram.

15.3 SHRU Signal Path

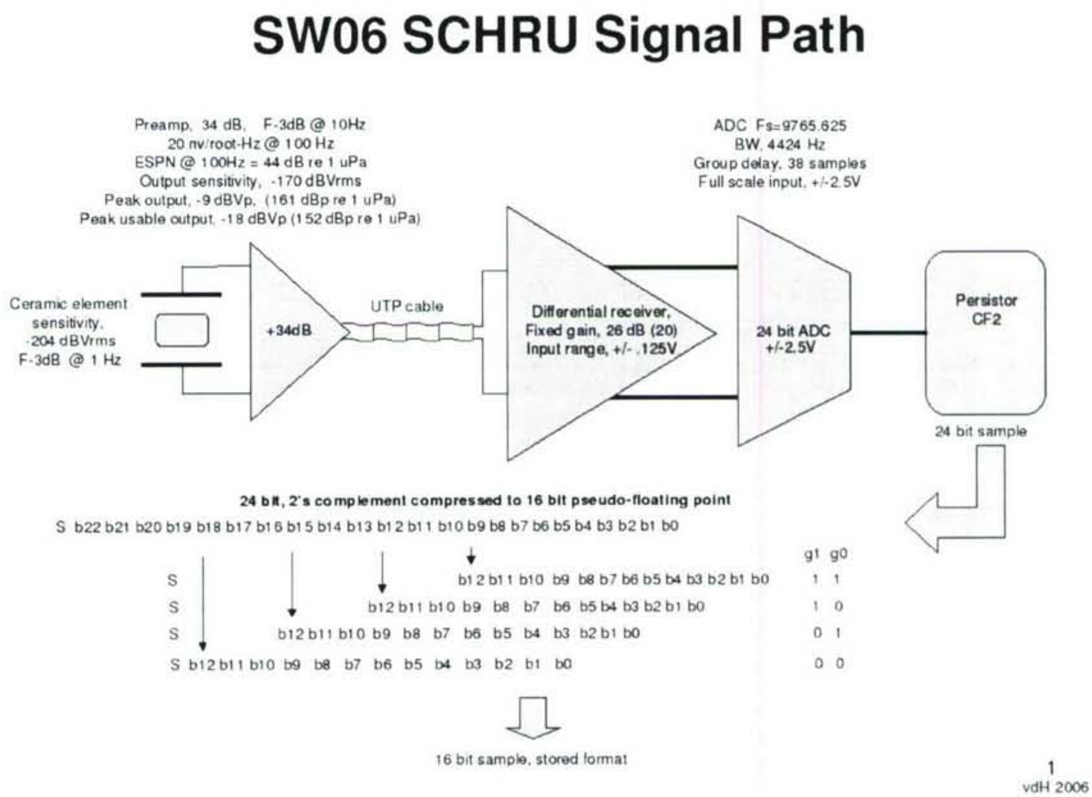

Figure 15.2.1: SHRU signal path.

15.4 Shark Signal Path

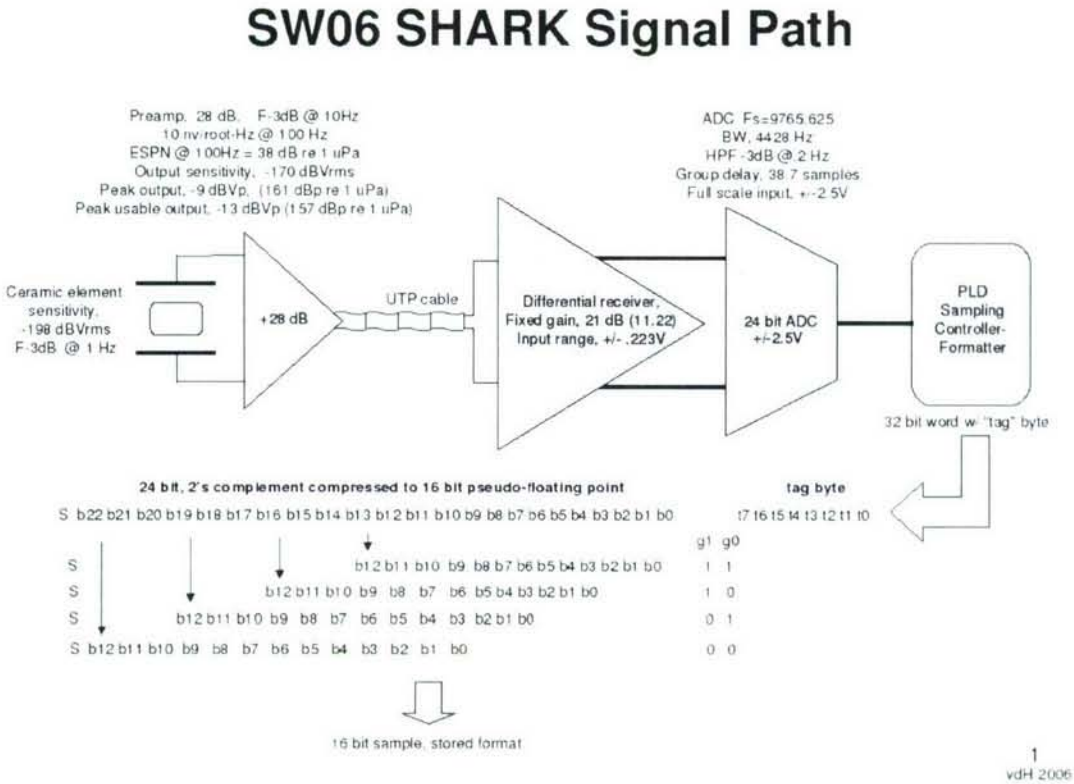

Figure 15.3.2: Shark signal path.

50272-101

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16. Abstract (Limit: 200 words)

This document describes data, sensors, and other useful information pertaining to the moorings that were deployed from the R/V *Knorr* from July 24th to August 4th, 2006 in support of the SW06 experiment. The SW06 experiment was a large, multi-disciplinary effort performed 100 miles east of the New Jersey coast. A total of 62 acoustic and oceanographic moorings were deployed and recovered. The moorings were deployed in a "T" geometry to create an along-shelf path along the 80 meter isobath and an across-shelf path starting at 600 meters depth and going shoreward to a depth of 60 meters. A cluster of moorings was placed at the intersection of the two paths to create a dense sensor-populated area to measure a 3-dimensional physical oceanography. Environmental moorings were deployed along both along-shelf and across-shelf paths to measure the physical oceanography along those paths. Moorings with acoustic sources were placed at the outer ends of the "T" to propagate various signals along these paths. Five single hydrophone receivers were positioned on the across shelf path and a vertical and horizontal hydrophone array was positioned at the intersection of the "T" to get receptions from all the acoustics assets that were used during SW06.

17. Document Analysis a. Descriptors

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acoustic and physical oceanography data
SW06 mooring information

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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